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Textile Yarn Abrasion Test

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TELEPHONE cords are subjected in service to wear conditions that cause kinking, bending, and abrasion. Such treatment causes fraying of the braided textile covering and leads eventually to the necessity of replacing the cords. As part of the continuing study to develop cords which will have maximum life for minimum cost, tests have been made in the Bell Telephone Laboratories on the resistance to abrasion of the textile yarns used in the braided covering of cords. The test to be described here was an important one leading to treatments that have been employed to improve the wearing quality of the textiles used for covering cords.

Abrasion tests on textiles have, with reason, been considered of doubtful or limited value because of the difficulty of interpreting results. A recent statement on this subject follows:

"It is generally recognized that the results of abrasion tests on cloth cannot always be adequately interpreted since the conditions which govern the wearing of any cloth under service conditions are obviously so complex that it is impossible to imitate them exactly in any one laboratory test. For this reason the majority of people are rightly sceptical as to the value of laboratory wear tests" [1].

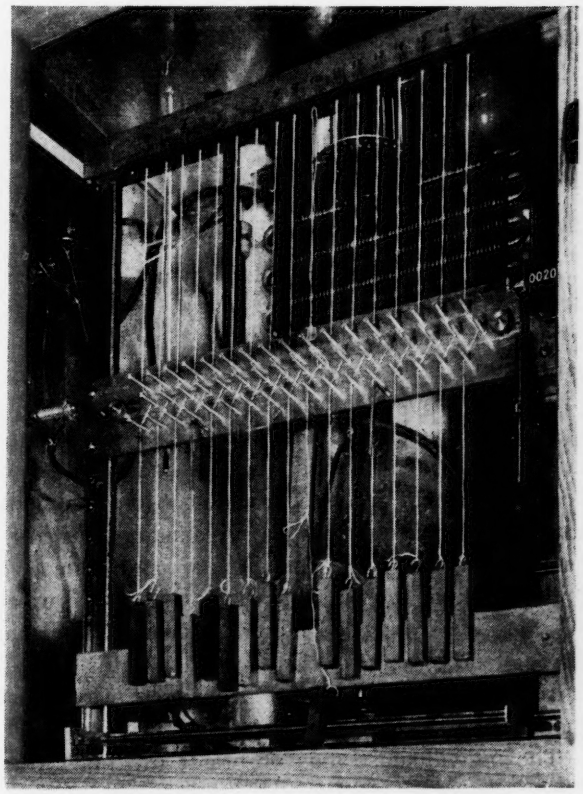

FIG. 1. *Photograph of yarn abrasion apparatus.*

The general acceptance of such a viewpoint has increased the onus of proof of the usefulness of the yarn abrasion test described here. It was not until the results were shown to give reliable indications of the probable results with other more complex tests simulating service conditions that it was agreed to consider yarn abrasion data as an important adjunct in the design and improvement of cords. Now it is believed that the extension of this test to the study of the wearing quality of textile yarns which are to be made into various types of fabrics will have even more economic advantages than were derived from its application to the life of telephone cords.

Objectives

Briefly, the purpose of this paper is threefold:

1. To describe the new yarn abrasion test;
2. To show how careful planning of experiments, together with the aid of statistical quality control analysis, has
   (*a*) Provided evidence of the reliability of the test;
   (*b*) Assisted in discovering clues to assignable causes of variability;
3. To illustrate by example how statistical quality control analysis may prove useful for other types of data, particularly in research and design, whether on textile or other industrial problems.

Description of Abrasion Test

This test applies a controlled amount of localized wear or rubbing between strands or braids of yarn, repeated at consecutive intervals of time until breakage occurs. The number of strokes (i.e., consecutive operations) to failure is taken as a measure of the wearing quality. The test fixture is mounted in a cabinet (Figure 1) which is metal-lined and heat-insulated in order to provide constant temperature and humidity conditions surrounding the textile during test. A simple method of controlling humidity within such a cabinet has been described [2, 3]. If a controlled humidity room is available, it is not necessary to enclose the apparatus in such a cabinet, and, therefore, tests may be made much more rapidly.

The individual strands or braids are hung from hooks located on a stationary crossbar with weights fastened to the free end of each. The mid-portion of each strand is trained about staggered pins mounted on a movable plate, as shown in Figure 2. A loop is made about a middle pin so that there is a cross-over at a sharp bend. As the plate holding these pins moves up and down, actuated by a motor-driven cam, the yarn is rubbed upon itself and wear occurs in the sharp bend. Depending upon the length of the stroke, which may be varied from ¼ inch to 3 inches by the cam, a corresponding length of yarn is involved in this abrasive action. For some tests, a double length of yarn, in the form of an endless loop, was mounted for test as a double strand. One end of this loop was hung over the support and the other end attached to the weight, to equalize the stresses on the two strands. Multiple-ended braids were mounted in the manner described for single strands. With a given weight, double strands wear much longer than single ones and the ratio may vary with the kind of textile. All data in this paper were obtained with 100-gram weights on single or double

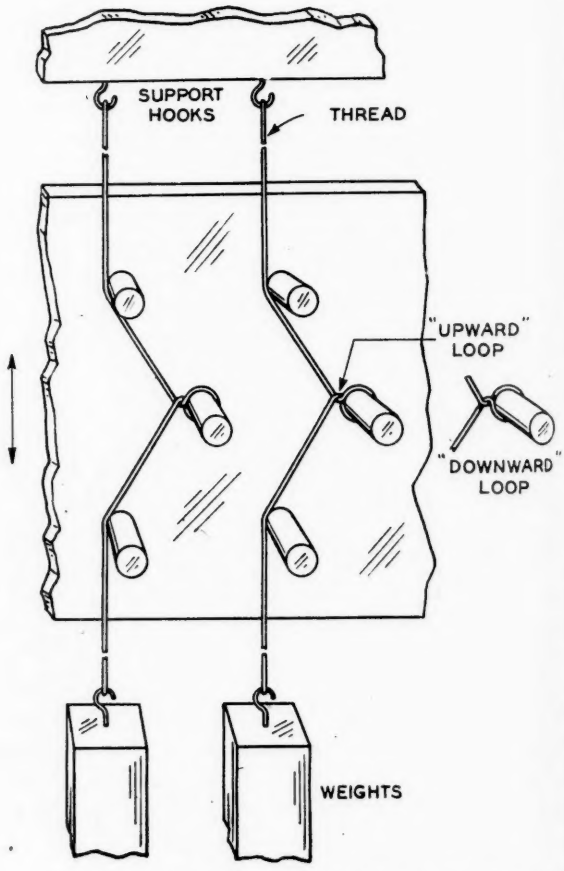

FIG. 2. *Method of mounting strands on abrasion apparatus.*

strands of 24/3 ply or 10/3 ply cotton. The tests on single strains were completed in a few minutes; those on double strands in one to two hours. It is desirable to make preliminary trials to determine the weight that should be used to give a reasonably short testing interval for each kind of textile.

Initially, the yarn abrasion test was set up with no strand loop about the middle pin, the yarn simply rubbing on the surfaces of three staggered pins. These surfaces were abrasive, being of sand-blasted glass, quartz, or sapphire. These roughened surfaces, although they gave comparable results at first, became polished with use or filled with abrasion products, causing the average number of strokes to failure to increase progressively and to become more variable. The setup finally adopted, shown in Figure 2, employs smooth chromium-plated steel pins merely as guides to facilitate the rubbing of strand on strand. The wear on these smooth guides is negligible. Without the loop, strands have operated for 50,000 strokes or more with no appreciable evidence of wear.

The testing conditions used in this work were selected as the result of much investigation involving not only the kind of abrasive surface but the speed of operation, length of stroke, diameter and separation of pins, and the amount of staggering of the middle row with respect to the top and bottom row of pins. The conditions selected were:

Speed of operation—35 strokes per minute
Length of stroke—$\frac{7}{8}$ inch
Diameter of pins—$\frac{3}{16}$ inch
Pin separation—Top and bottom row—$1\frac{1}{2}$ inches
Top or bottom to middle row—$\frac{3}{4}$ inch (measured vertically)

The center row of pins is mounted on a separate narrow bar fitted into a groove in the movable plate. This bar may be adjusted to give as much as $\frac{1}{2}$ inch displacement of the center pins with respect to the top and bottom rows so as to achieve various angles of bend in the strand loop. The maximum displacement was used for all tests reported here. In applying this test to other textiles than those studied, the conditions selected should be the subject of additional investigation. However, the methods of planning tests and interpreting the results described in this paper may be used to advantage.

Although it is presumed that the direction of twist of the loop about the middle pin relative to the direction of the yarn twist would affect the results, no conclusive test of this has been made. For the sake of uniformity in the experimental work under discussion, the twist of the loop about the middle pin was such that it caused tightening of the yarn twist on the down stroke; for S-twist yarns, the loop would be made opposite that for Z-twist yarns.

With single strands, the normal twist is retained throughout the test by resting the square weights lightly against a properly located backing plate. In operation, the motor-driven plate moves up and down until a strand breaks and the associated weight falls upon a crossbar. This impact is transmitted through the bar to a micro-switch in the motor circuit. Tripping this switch stops the motor, which can be started again only by manually operating another switch. A counter, shown in Figure 1, records the number of strokes. The apparatus was designed to test seventeen separate lengths of yarn at one time, each strand being 16 to 18 inches long. The choice of seventeen positions was dictated by convenience. In redesigning the apparatus, other considerations suggest the use of twenty-four positions.

Material Examined and Scope of Tests

Many types of textile yarns have been tested with this apparatus, but data are given here on only a few, simply to show the worth of the method and to illustrate the application of statistical quality control analysis to several problems of common interest to the textile industry. The discussion here refers to tests made on three particular lots of cotton yarn, a 24/3 ply brown dyed mercerized brown cotton, a 10/3 ply bleached white cotton, and a 24/3 ply red dyed cotton. The data presented were obtained in a total time equivalent to about six working days and comprise nearly a thousand observations.

Character of Abrasion Tests

1. *Limitations.* Abrasion tests have several limitations: they are destructive in character; they are not reproducible in the same sense that repeated measurements may be made on the same specimen; and in many there is no finite end-point, failure being a matter of judgment—e.g., the degree of fraying of a textile or the amount of material removed by abrasion. In addition, if a test is time-consuming, requiring thousands of operations, or is expensive to make, as are many destructive tests, it is impractical

TABLE I. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—24/3 PLY BROWN MERCERIZED YARN *
Data listed in order of specimen selection from skein

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	135			16	77			5	50		
6	105			10	77			15	89		
2	107		61	7	77		10	17	147		97
7	74	105.2		3	87	79.5		8	82	92.0	
13	75			11	96			6	103		
11	101			2	82			16	78		
14	115		40	17	102		41	9	74		29
12	106	99.2		9	61	85.2		7	101	89.0	
4	93			6	73			13	70		
8	148			13	111			11	96		
15	97		55	8	84		38	1	85		26
5	148	122.0		1	110	94.5		3	92	85.8	
9	89			5	84			E 12	107		
16	75			12	97			14	87		
3	121		46	C 15	100		16	8	82		31
1	121	101.5		16	110	97.8		6	76	88.0	
A† 10	142			3	96			2	76		
15	78			15	72			15	93		
3	75		67	9	71		25	11	62		31
16	97	98.0		12	88	81.8		5	76	76.8	
2	122			2	72			13	107		
5	90			4	83			10	111		
9	92		32	10	77		14	4	77		41
12	110	103.5		13	69	75.2		7	118	103.2	
8	106			17	79			16	90		
11	106			6	82			12	96		
1	122		16	8	93		43	1	57		39
14	120	113.5		5	50	76.0		17	82	81.2	
17	95			11	77			3	99		
13	108			14	63						
4	82		26	7	76		14	F 9	84		
6	95	95.0		D 1	72	72.0					
10	73			10	93			$\bar{X}$ = 91.5			
B 7	137			4	78			$\bar{R}$ = 38 (samples of four)			
14	104		74	2	51		42	UCL = 116.5			
4	63	94.2		14	90	78.0		LCL = 66.5			

* *Nomenclature for All Tables*
$\bar{X}_4$ = Average of samples of four
R_4 = Range of samples of four
$\bar{X}$ = Grand average
$\bar{R}$ = Average range from samples
Statistical control limits for average:
UCL = upper control limit
LCL = lower control limit

† Letters A through F indicate the ends of groups of 17 specimens.

to test fifty to a hundred specimens from each sample. Nevertheless, if the variability of the yarn composing a fabric is of the order of that indicated by data cited in this paper, then the usual number of tests that are made, about five or fewer, seems woefully inadequate to evaluate the wearing quality of such a material. The author quoted on page 201 passively accepts the sceptical attitude generally held regarding abrasion tests without considering what might be done to overcome such limitations as these.

2. *Advantages of the Yarn Abrasion Test.* The yarn abrasion test has several advantages: relatively large numbers of separate specimens may be tested in a reasonably short time and at low expense; each

TABLE II. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—24/3 PLY BROWN MERCERIZED YARN (REARRANGEMENT OF TABLE I) *

Data listed in order of break
Random groups of 17

Rank by order of break	Group No. 1	2	3	4	5	6	$\bar{X}_6$	R_6
	Strokes							
1	51	72	63	50	69	50	59.2	22
2	61	72	70	57	75	74	68.2	18
3	62	82	76	63	76	74	72.2	20
4	72	83	77	71	79	75	76.2	12
5	75	84	77	73	82	77	78.0	11
6	76	84	78	73	87	77	79.2	14
7	76	87	82	77	90	78	81.7	14
8	78	90	84	77	92	82	83.8	15
9	93	96	85	82	93	95	89.7	14
10	96	99	89	82	93	97	91.7	17
11	97	100	90	88	95	103	94.5	15
12	104	102	92	89	97	106	97.3	17
13	110	105	93	96	101	106	100.8	17
14	122	107	96	107	101	106	105.5	28
15	147	108	110	111	110	107	114.5	40
16	148	137	118	115	111	120	123.8	37
17	148	142	135	121	122	121	130.5	27
Σ_{17}	1,616	1,650	1,515	1,432	1,573	1,548		
$\bar{X}_{17}$	95.1	97.1	89.1	84.2	92.5	91.1		
$\bar{R}_{17}$ =	12.9							
$\bar{X}$ =	91.5							

* *Nomenclature*
$\bar{X}$ = Grand average (for 102 specimens).
$\bar{X}_6$ = Average of six groups for each rank.
R_6 = Range of six groups for each rank.
Σ_{17} = Sum of number of strokes for each group.
$\bar{X}_{17}$ = Average number of strokes for each group.
$\bar{R}_{17}$ = Range of average number of strokes for the six groups.

specimen is worn to definite breaking values; some information may be obtained on the wearing qualities of textiles by precise measurements of the variability of the yarn itself with such a quantitative end-point test. The agreement between abrasion data on cotton yarns used as braids on telephone cords and data obtained by laboratory wear tests on such cords, mentioned in the first paragraphs of this paper, indicates that such information has very practical value. Furthermore, it will be shown that even if this test is not reproducible in the sense mentioned in "Limitations," page 203, it is possible to show that the test is capable of giving statistically reproducible results.

Application of Statistical Quality Control Analysis to Abrasion Data

1. *Planning of Tests.* Much can be done to evaluate accelerated destructive tests provided attention is given to the manner in which the test procedure is planned and to the use of suitable statistical methods in the analysis of the results. This emphasis on planning and analysis is important. For example, consider Table I. In planning the original experiment, the yarn specimens were mounted at random on the 17 pin positions. Each consecutive yarn specimen taken from the package was allocated to a given pin as determined by the random selection of numbers from 1 to 17.[1] For example, the first specimen from the package was mounted on position 17, the second on 6, and the last of the first group of 17 was mounted on 10. After breaking all of this group, the next was mounted according to another random selection of these numbers, the first specimen being assigned to position 15. This procedure was repeated for the remaining four groups, and the letters A to F in Table I indicate the end of each group of 17 specimens. The reason for using this random selection was to remove the effect of assign-

[1] Allocation at random was made in the sense described by W. A. Shewhart in his book *Statistical Method from the Viewpoint of Quality Control* [4]. The actual process was to place in a bowl 17 chips, numbered from 1 to 17 to correspond to the 17 pin positions. The chips were mixed, then drawn one at a time, and their order recorded. This process was repeated to obtain six groups of 17, or a total of 102 drawings.

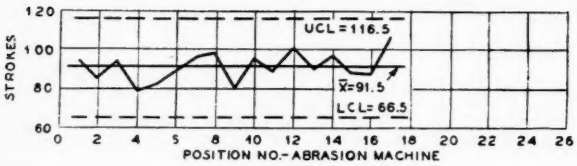

FIG. 3. *Control chart of abrasion resistance showing apparatus reproducibility. Single strands—24/3 ply brown mercerized cotton. Averages of six for each pin position. Data in Table III.*

able variation along the yarn, should it exist, and to permit comparison of the results for each pin position.

2. *Reproducibility of the Test Method.* Table II is a rearrangement of the data in Table I. The results are presented in an ordered array from minimum to maximum abrasion resistance for six groups of seventeen specimens each. The 102 consecutive results in Table I were reallocated at random [2] so that each of the six groups of seventeen values included one test for each pin position. The poorest specimen broke at 50 strokes, and the best at 148, a range of about three times the minimum value.[3] It will be observed from Table II that the first break in each group occurred after 51, 72, 63, 50, 69, and 50 operations respectively. The average and range for these are 59.2 and 22. Similarly, the average and range may be set down, as shown in the last two columns of Table II, for each of the other rows and for the averages of the columns. It is apparent from this table that, despite the wide range existing between the minimum and maximum observations, there is a certain degree of constancy from column to column, a kind of constancy that may be examined more precisely by the methods of engineering statistics.

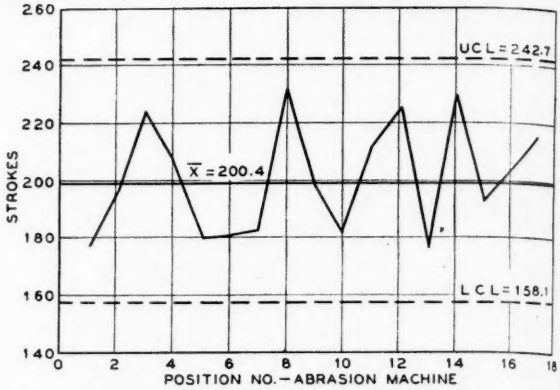

FIG. 4. *Control chart of abrasion resistance showing apparatus reproducibility. Single strands—10/3 ply bleached cotton. Averages of six for each pin position. Data in Table IV.*

The data are again rearranged in Table III, to show the breaks for each pin position, and it will be seen that there are 6 specimens per pin. The control chart [4] (Figure 3) portrays these sub-group

[2] For this allocation, six chips, corresponding to the six consecutive groups of 17, were placed in a bowl, mixed, drawn one at a time, and the order recorded. This was repeated to obtain 17 groups of six, or 102 drawings. The consecutive tests on pin 1 were assigned to the six new groups of 17 in accordance with the first drawing of six, the tests on pin 2 with the second drawing, and so on. Then each new group of 17 was arranged in order of break.

TABLE III. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—24/3 PLY BROWN MERCERIZED YARN (REARRANGEMENT OF TABLE I)

Data listed in order of position mounting for each lot of 17

Pin No.	Lot designation A	B	C	D	E	F	$\bar{X}_6$*	R_6
	Strokes							
1	121	122	110	72	85	57	95	65
2	107	122	82	72	51	76	85	71
3	121	75	87	96	92	99	95	46
4	93	82	63	83	78	77	79	30
5	148	90	84	50	50	76	83	98
6	105	95	73	82	103	76	89	32
7	74	137	77	76	101	118	97	63
8	148	106	84	93	82	82	99	66
9	89	92	61	71	74	84	79	31
10	142	73	77	77	93	111	96	69
11	101	106	96	77	96	62	90	44
12	106	110	97	88	107	96	101	22
13	75	108	111	69	70	107	90	42
14	115	120	104	63	90	87	97	57
15	97	78	100	72	89	93	88	28
16	75	97	77	110	78	90	88	35
17	135	95	102	79	147	82	107	68
	$\bar{\bar{X}}$ = 91.5					UCL = 116.5		
	$\bar{R}$ = 51.0 (samples of six)					LCL = 66.5		

* $\bar{X}_6$ = Average of samples of six for each pin position.
$\bar{R}_6$ = Range of samples of six for each pin position.

[3] With double strands from the same package the corresponding range was 277 to 1,330, for 85 specimens (data not given). Another type of yarn (Table V) ranged from 83 to 281 for singles, and from 794 to 2,567 for double strands (Table XIII). Application of a starch finish to this latter yarn made the range for double strands from 904 to 8,432 (Table XIV). Thus ranges of from about three to ten times the minimum values are observed in these yarn abrasion tests on 3-ply yarns. The range may vary with both the treatment and the kind of yarn. For example, in preliminary tests on a 21 single-ply cotton yarn, ranges up to one hundred times the minimum abrasion values have been observed. Obviously much greater proportionate ranges may be observed with single strand than with multiple-end yarns.

[4] This chart, as well as all similar charts in this paper, was prepared in accordance with quality control procedures outlined in *American War Standards*, Z1.1, Z1.2, and Z1.3 [5].

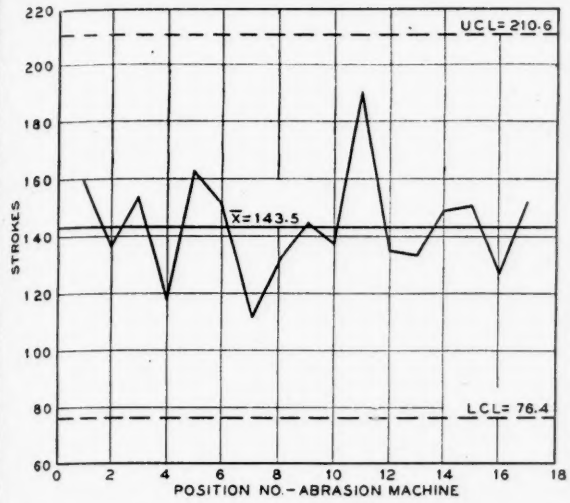

FIG. 5. *Control chart of abrasion resistance showing apparatus reproducibility. Single strands—24/3 ply red glazed cotton. Averages of six for each pin position.*

averages of 6 tests for each pin. This chart shows that all points are within control limits, with strong concentration near the average. Similar charts have been prepared on each set of yarn tests made in this investigation. Table IV and the two pin-position control charts, Figures 4 and 5, are additional examples. In every case the data have provided evidence to support the conclusion that the method of test is such that the results are statistically reproducible and independent of pin position. Therefore, data obtained with this method of test may be examined with considerable confidence that any points observed outside the statistical control limits are caused by assignable variations in the yarn itself.

3. *Variations in Abrasion Resistance Along the Length of the Yarn.* It is recognized, of course, that textiles may show variations in quality along the length of the yarn. In an attempt to evaluate such irregularities, specimens were taken in consecutive order, as indicated by the arrangement of data in Table I.[5] A control chart of these data, Figure 6, based on consecutive averages of fours, shows evidence of lack of control in that one group of four

[5] The abrasion test concentrates the wear along only a small fraction of the length of the test specimen. Thus about ½ inch to 1 inch of each 16 to 18 inch specimen is involved. Consequently, these data do not represent the wearing quality of every inch of yarn, but, because the strands are cut to exact lengths and mounted in a systematic manner, they do provide a measure of some types of variation that might be expected when consideration is given to the manufacturing operations employed in the production of textiles.

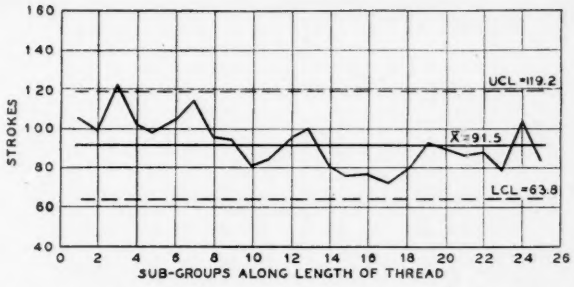

FIG. 6. *Control chart of abrasion resistance. Single strands—24/3 ply brown mercerized cotton. Averages of four taken consecutively along yarn length. Data in Table I.*

observations has an average value above the upper control limit. Having determined that causes are present that need not be left to chance, the next step is to examine for the type of cause. It is noted that each of the first 9 consecutive averages is higher than each of the 10 consecutive averages from 14 to 23 inclusive. These are commonly called runs of lengths 9 and 10, respectively. An arrangement with 9 or more consecutive values higher than each of 9 or more consecutive values would be expected to occur less frequently than one time in one thousand in a random drawing from a bowl containing 25 chips, numbered from 1 to 25 to correspond to the

TABLE IV. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—10/3 PLY BLEACHED YARN

Data listed in order of position mounting for each lot of 17 specimens
Skein-conditioned and tested at 65% R.H.—70°F

Pin No.	A	B	C	D	E	F	$\bar{X}_6$*	R_6
1	172	193	201	159	184	144	176	57
2	276	171	169	214	183	170	197	106
3	276	235	178	307	165	180	224	139
4	275	235	214	205	145	164	206	130
5	188	206	135	203	187	157	179	71
6	229	160	138	159	161	241	181	103
7	206	200	154	208	141	181	182	67
8	244	257	269	221	233	161	231	108
9	179	187	227	189	200	197	197	48
10	181	146	173	198	213	168	180	67
11	261	208	220	176	199	205	212	85
12	206	254	244	223	270	150	225	120
13	167	170	195	199	173	148	175	51
14	219	275	199	217	281	179	228	102
15	178	218	189	219	198	147	192	72
16	199	184	161	241	193	237	203	80
17	229	192	184	217	202	267	215	83

$\bar{\bar{X}}$ = 200.4 UCL = 242.7
$\bar{R}$ = 87.59 LCL = 158.1

* $\bar{X}_6$ = Average of samples of 6 for each pin position.
R_6 = Range of samples of 6 for each pin position.

TABLE V. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—24/3 PLY RED UNTREATED YARN *

Data listed in order of selection from package
Package-conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	111			17	171			2	125			12	281		
6	117			13	165			4	111			14	187		
2	132		39	4	95		135	10	188		78	8	228		48
7	150	128		6	230	165		13	189	153		6	180	219	
13	194			10	136			17	83			2	188		
11	159			7	132			6	150			15	115		
14	134		60	14	142		30	8	157		74	11	146		101
12	173	165		4	162	143		5	140	133		5	216	166	
4	103			16	157			11	162			13	170		
8	111			10	157			14	219			10	164		
15	233		130	7	156		37	7	133		86	4	243		79
5	145	148		3	120	148		1	188	176		7	187	191	
9	144			11	168			10	189			16	116		
16	91			2	101			4	240			12	138		
3	107		53	17	136		148	2	132		108	1	109		47
1	121	116		9	249	164		14	222	196		17	91	113	
10	101			6	183			5	147			3	117		
15	176			13	89			15	112			9	224		
3	138		75	8	106		94	17	174		62	13	155		155
16	164	145		1	162	135		8	169	151		15	270	191	
2	102			5	104			6	205			11	146		
5	170			12	133			16	175			12	157		
9	174		82	15	109		101	9	147		58	6	90		90
12	92	135		16	205	138		7	183	178		9	180	143	
8	159			3	144			13	205			3	142		
11	148			15	111			11	170			10	121		
1	170		33	9	181		72	1	236		66	17	148		27
14	181	165		12	109	136		3	190	200		4	134	136	
												7	169		
												16	199		
												14	224		29
												1	165	189	

$\bar{X}$ = 157.45
$\bar{R}$ = 75.76

UCL = 212.68
LCL = 102.22

* See Table I for nomenclature.

magnitudes of the 25 averages in Table I. Past experience with other engineering data has shown that sudden shifts and trends are often associated with findable causes. Both of these observations are consistent with the hypothesis that a shift in average is associated with the assignable cause. Whether this shift is an abrupt change in level or a trend is not known, but this could be ascertained by new experiments designed for the purpose. For example, a change in the testing arrangement could be worked out to permit using shorter lengths of material and thereby provide more detailed information concerning the variation along yarn length. Such an investigation may be of value to textile manufacturers as a means for improving the uniformity of their product.

Additional information concerning the type of cause may be obtained very simply by examining the original data for runs. For example, in Table I, each of the consecutive values 97, 122, 90, 92, 110, 106, 106, 122, 120, 95, and 108, a run of length 11, is higher than each of the consecutive values 72, 71, 88, 72, 83, 77, 69, 79, and 82, a run of length 9. On the basis of considerations similar to those stated above for the 25 chips, an arrangement with groupings of 9 or more would be expected to occur less

TABLE VI. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—24/3 PLY RED UNTREATED YARN *

Data listed in order of selection from skein
Skein-conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	195			11	205			13	167			11	146		
6	104			2	182			11	120			9	138		
2	145		91	17	156		123	1	185		65	16	216		143
7	166	153		9	82	156		3	167	160		5	281	195	
13	210			6	150			12	114			3	188		
11	82			13	183			14	137			4	115		
14	130		128	8	108		75	8	221		107	13	228		113
12	92	129		1	102	136		6	167	160		6	187	180	
4	178			5	150			2	144			14	164		
8	122			12	125			15	266			10	91		
15	154		76	15	124		35	11	220		122	7	224		133
5	102	139		16	159	140		5	159	197		12	155	159	
9	98			3	308			13	265			2	270		
16	68			15	112			10	239			8	168		
3	114		47	9	142		196	4	203		162	17	157		180
1	115	99		12	219	195		7	103	203		1	90	171	
10	134			2	140			16	273			4	180		
15	86			4	115			12	229			9	142		
3	117		54	10	133		204	1	142		142	17	121		59
16	140	119		13	319	177		17	131	194		12	148	148	
2	95			17	113			3	148			11	134		
5	108			6	126			9	157			16	169		
9	73		64	8	147		35	13	214		82	14	199		190
12	137	103		5	148	134		15	230	187		15	224	182	
8	105			11	206			11	105			7	165		
11	60			14	242			12	156			5	254		
1	102		45	7	133		109	6	155		51	6	217	212	
14	96	91		1	154	184		9	146	141					
17	137			10	157			3	133						
13	107			4	194			10	224						
4	86		51	2	73		121	17	138		101				
6	101	108		14	171	149		4	123	155					
10	95			5	131			7	153			$\bar{X}$ = 152.51			
7	97			15	242			16	187			$\bar{R}$ = 100.			
14	139		44	17	137		111	14	109		78	UCL = 225.4			
4	127	115		8	187	174		1	180	157		LCL = 79.6			
16	116			6	100			2	115						
10	134			16	97			8	116						
7	85		53	9	175		78	5	170		128				
3	138	118		7	136	127		15	243	161					

* See Table I for nomenclature.

than two times in one hundred in a random drawing from a bowl containing 102 chips, numbered [6] to correspond to the magnitudes of the observations in Table I. The observed arrangement, however, is consistent with the hypothesis suggested by experience that each of such long runs is representative of a temporary shift in average level. This is a more tenable hypothesis from an engineering viewpoint than that both are the random result of a controlled condition for all of the measurements. Tables V

[6] The presence of some duplicate values in the observations reduces the possible occurrences.

and VI show data for consecutive lengths of another cotton. To provide a graphical illustration, the individual values are plotted in Figures 7 and 8, respectively. Figure 7 shows runs of length 10 and 11, as indicated, whereas Figure 8 shows a run of 29 consecutive observations with values below the median of the group. An arrangement with a run of this length or more, on one side of the median, would be expected to occur in a random drawing of 148 chips less than one time in ten million. This means it is very unlikely that an arrangement with a run of this length or more, under conditions where no shifts or trends are present, would be obtained. Engineering experience, however, has shown that shifts and trends are often associated with findable causes. These considerations suggest that the observed data show a change in level that is associated with such a cause. It is reasonable,[7] therefore, to compare the average of the group of 29 observations with the average of the remainder in considering the economic importance of such differences in level of yarn quality as a basis for engineering action.

4. *Package Versus Skein Conditioning of Yarn Before Test.* In several cases it was observed that the outer layers of yarn on a package appeared to have a level of abrasion resistance different from the underlying layers. For example, note the distribution of averages in Figure 6 and the related discussion in the preceding section. Such differences might be related to variations along the length of the yarn or perhaps to the way in which the yarn was conditioned before testing. To examine the conditioning possibility, the data on 24/3 ply red untreated cotton (Tables V and VI) were secured according to the following plan: those in Table V were obtained on consecutive specimens taken directly from a package of yarn which had been conditioned for several days at 65 percent relative humidity and 70°F, whereas those in Table VI were from a skein unwound from this package after the specimens were obtained for Table V. This loose skein of yarn was identified to retain the sequence of sampling and then conditioned for an additional 24 hours

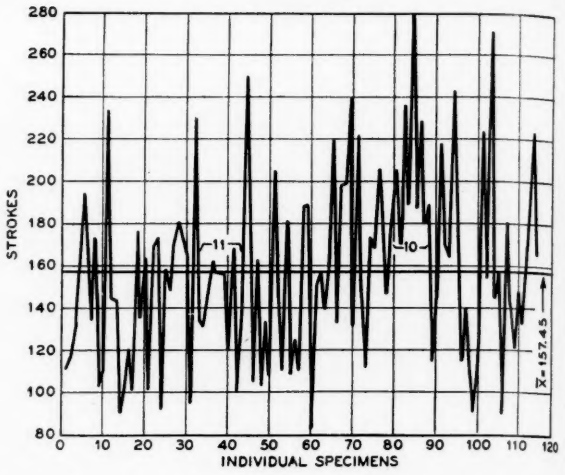

FIG. 7. *Abrasion resistance chart of individual specimens. Single strands—24/3 ply red untreated cotton. Consecutive specimens taken along yarn length. Package-conditioned yarn. Data in Table V.*

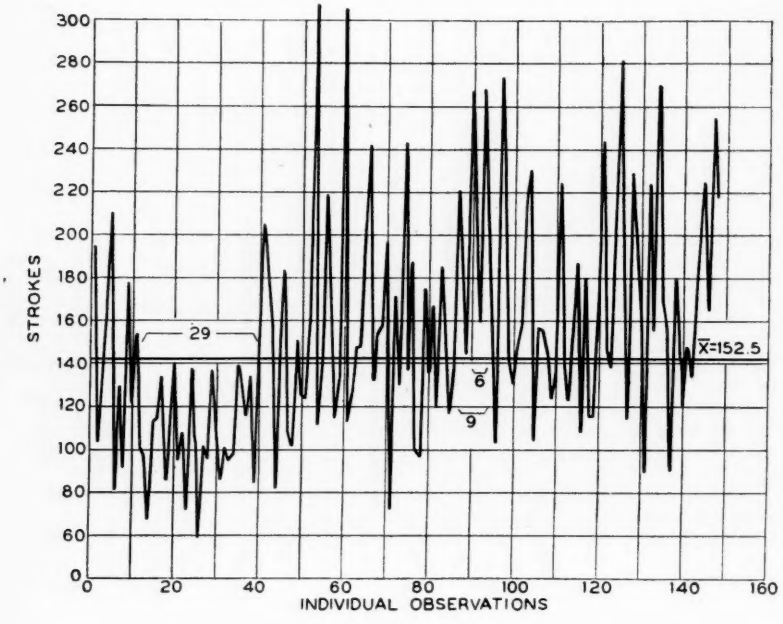

FIG. 8. *Abrasion resistance chart of individual specimens. Single strands—24/3 ply red untreated cotton. Consecutive specimens taken along yarn length. Skein-conditioned yarn. (Continuation of data in Figure 6.) Data in Table VI.*

[7] The meaning of "reasonable" as used here is discussed in *Statistical Method from the Viewpoint of Quality Control*, by W. A. Shewhart [4].

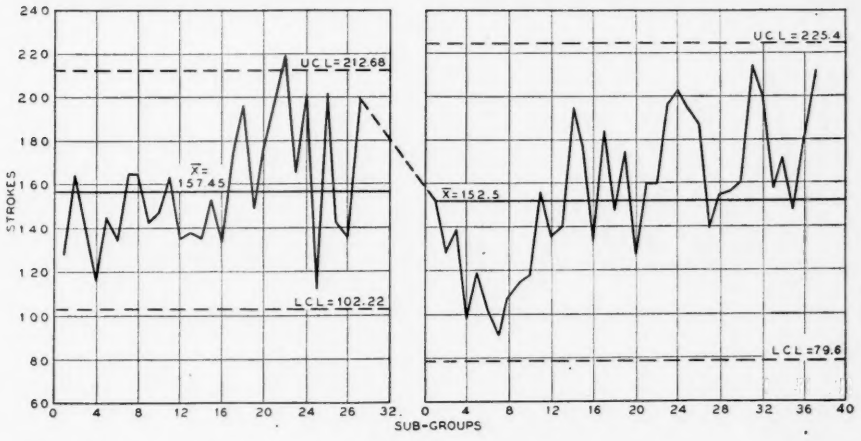

FIG. 9. *Control chart of abrasion resistance. Single strands—24/3 ply red untreated cotton. Averages of four taken consecutively along yarn length. Data in Tables V and VI. Left—Package-conditioned yarn. Right—Skein-conditioned yarn.*

before testing. Thus all of the data in these two tables are in continuous sequence of specimens from the length of yarn, as indicated by the dotted line in the control chart of averages of consecutive sub-groups of 4 specimens each in Figure 9.

The data for the package-conditioned yarn (Figure 9) show evidence of lack of control in that one sub-group average of 4 is outside the upper range limit. The data for the skein-conditioned yarn, with 144 observations, show all averages to be well within control limits, but there is indication of a difference in the level of quality along the length of the yarn because the sub-group averages from 2 to 10 are all below the sub-group averages from 21 to 36. An arrangement with two such consecutive groups of 9 or more would be expected to occur in a random drawing about one time in one thousand. While these differences in the two charts on Figure 9 are of interest, there is no clear indication of a conditioning effect. The difference between the average values of 157.45 and 152.5 for the two sets of data is not considered pertinent to the question of conditioning, particularly because assignable variations exist in both tests.

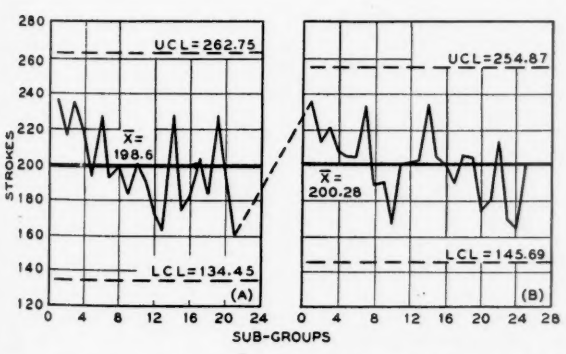

FIG. 10. *Control chart of abrasion resistance. Single strands—10/3 ply bleached cotton. Averages of four taken consecutively along yarn length. Data in Tables VII and VIII. Left—Package-conditioned yarn. Right—Skein-conditioned yarn.*

Additional evidence regarding this question of conditioning is given by the data in Tables VII and VIII, which are plotted on the control chart of Figure 10. These results are divided into package- and skein-conditioned groups, as before. In Figure 10, it is seen that the averages of the two sets of data differ but little. Statistical test shows that the observed difference is 0.3 times its standard deviation. The probability of observing a difference between the standard deviations of the two groups, as large or larger than that computed from the average ranges of fours, is approximately 0.1, on the basis that both groups are random samples from a single normally distributed universe. The ranges of averages of fours in the two charts are almost identical—viz., from 160 to 235 in the package-conditioned group, and from 165 to 235 in the skein-conditioned group—with all values well within control limits. All of these findings are consistent with the hypothesis that the difference in the manner of conditioning the yarn described here had little or no effect on abrasion resistance. The question of conditioning at other humidities has not been studied.

5. *Possible Cyclic Variation Along Yarn.* To the production engineer, the evidence in the preceding section is adequate for the conclusion reached. To the engineering statistician, the control chart of Figure 10 is unusual because it reveals such good evidence for control although, so far as is known, quality control methods had not been used in the manufacture of this yarn. Experience has shown that it is almost always necessary to make changes in manu-

TABLE VII. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—10/3 PLY BLEACHED YARN *

Data listed in order of selection from package
Package-conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	169			16	185			5	353		
6	217			10	188			15	171		
2	323		154	7	182		62	17	241		207
7	229	235		3	244	200		8	146	228	
13	205			11	197			6	159		
11	216			2	147			16	253		
14	262		78	17	210		64	9	151		102
12	184	217		9	211	191		7	185	187	
4	294			6	143			13	175		
8	277			13	239			11	191		
15	194		123	8	159		96	1	119		72
5	171	234		1	146	172		3	155	160	
9	210			5	144			12	212		
16	162			12	204						
3	252		90	15	148		60				
1	247	218		16	156	163					
10	176			3	276						
15	244			15	231						
3	166		78	9	173		103				
16	202	193		12	231	228					
2	230			2	156						
5	244			4	125						
9	191		53	10	195		93				
12	234	225		13	218	174					
8	178			17	187			$\bar{X}$ = 198.6			
11	156			6	211			R = 87.8			
1	246		90	8	172		47	UCL = 262.75			
14	187	192		5	164	184		LCL = 134.45			
17	160			11	254						
13	258			14	184						
4	177		98	7	187		70				
6	195	198		1	187	203					
10	165			10	198						
7	176			4	142						
14	230		69	2	186		60				
4	161	183		14	202	182					

* See Table I for nomenclature.

facturing procedures to reach a state of statistical control after the process is first subjected to quality control analysis. Therefore, these data were examined in other ways to ascertain whether the evidence of control was real or only apparent.

One way to obtain a chart of this type, with all points well within the control limits even if the material is not actually under control, would be to have short cycles in the observations. These might produce a high average range for samples of four and thereby give wide control limits for the averages. To test this hypothesis and form an estimate of the cycle length, the serial correlation [6] has been computed for pairs of observations up to a lag of 24 for

TABLE VIII. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—10/3 BLEACHED YARN *
Data listed in order of selection from skein
Skein-conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	229			16	161			5	187		
6	229			10	173			15	198		
2	276		70	7	154		24	17	202		46
7	206	235		3	178	167		8	233	205	
13	167			11	220			6	161		
11	261			2	169			16	193		
14	219		94	17	184		58	9	200		59
12	206	213		9	227	200		7	141	174	
4	275			6	138			13	173		
8	244			13	195			11	199		
15	178		97	8	269		131	1	184		34
5	188	221		1	201	201		3	165	180	
9	179			5	135			12	270		
16	199			12	244			14	179		
3	276		104	15	189		109	8	161		109
1	172	207		16	241	202		6	241	213	
10	181			3	307			2	170		
15	218			15	219			15	147		
3	235		54	9	189		118	11	205		58
16	184	205		12	223	235		5	157	170	
2	171			2	214			13	148		
5	206			4	205			10	168		
9	187		83	10	198		16	4	164		33
12	254	205		13	199	204		7	181	165	
8	257			17	217			16	237		
11	208			6	159			12	150		
1	193		82	8	221		62	1	144		123
14	275	233		5	203	200		17	267	200	
17	192			11	176			3	180		
13	170			14	217			9	197		
4	235		75	7	208		58				
6	160	189		1	159	190					
								$\bar{X}$ = 200.28			
								R = 74.88			
10	146			10	213			UCL = 254.87			
7	200			4	145			LCL = 145.69			
14	199		68	2	183		136				
4	214	190		14	281	206					

* See Table I for nomenclature.

the data in Table VIII.[8] These correlation values, with appropriate limit lines based on a probability of 0.05 for each tail, are listed in Table IX and are plotted in Figure 11. It will be noted that about

[8] Assuming N observations with values $X_1, X_2, \cdots X_L, X_{L+1}, \cdots X_N$ listed in order of occurrence, the serial correlation for a lag L is defined as:

$$ {}_LR_N = \frac{X_1X_{L+1} + X_2X_{L+2} \cdots + X_NX_L - \frac{\left[\sum_{i=1}^{N} X_i\right]^2}{N}}{\left[\sum_{i=1}^{N} X_i^2\right] - \frac{\left[\sum_{i=1}^{N} X_i\right]^2}{N}} $$

The exact and large sample distributions of ${}_LR_N$ under certain restrictions have been computed and tabled by Anderson. His tables have been extrapolated to give the limits used here:

A. For a positive tail of 5 percent—i.e., 5 percent of observed values of ${}_LR_N$ are expected to be algebraically larger than this limit.

B. For a negative tail of 5 percent—i.e., 5 percent of observed values of ${}_LR_N$ are expected to be algebraically smaller than this limit.

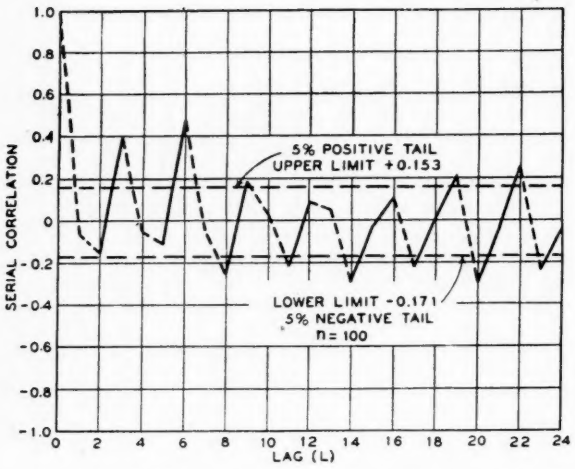

FIG. 11. *Serial correlation of abrasion resistance data. Single strands—10/3 ply bleached cotton. Data in Table IX.*

TABLE IX. SERIAL CORRELATION OF ABRASION RESISTANCE DATA ON 10/3 PLY BLEACHED YARN

Lag (L)	Correlation ($_LR_{100}$)
0	+1.000
1	−0.060
2	−0.151
3	+0.399
4	−0.051
5	−0.109
6	+0.487
7	−0.040
8	−0.259
9	+0.187
10	+0.035
11	−0.219
12	+0.095
13	+0.054
14	−0.290
15	−0.038
16	+0.103
17	−0.224
18	+0.008
19	+0.209
20	−0.296
21	−0.054
22	+0.250
23	−0.243
24	−0.041

Upper limit (based on 5% positive tail) = +0.153
Lower limit (based on 5% negative tail) = −0.171

half of the values are outside the limit lines and that a cycle of length approximately equal to 3 is indicated. Calculations for Table VII show a similar cyclic variation but with fewer correlation values outside the limits.

Before using serial correlations, known trends are usually eliminated; but since there is no accepted statistical test for a trend that does not extend through the entire set, this is not ordinarily possible. However, it is possible to make use of the tentative information suggesting a cycle of three, and prepare a new set of control charts using each third observation. This has been done for the data in Table VIII, is recorded in Table X, and is plotted in Figure 12. One important result is that the average range in samples of four is much lower than that for the original data and points are found outside control limits indicating that the apparent control in Figure 9 covered up underlying irregularities of interest to the design engineer. The corresponding charts of individual values in Figure 13 provide confirming evidence and indicate the order of magnitude of the effect.

Discussion with production workers in the textile industry indicates that there is a physical basis for cycles of this type in the process of making yarn. It is believed that use of shorter lengths of yarn for the abrasion tests might provide a simple basis for studying effects of this type.

6. *Comparison of Two Kinds of Yarn.* The average abrasion resistance of the 10/3 ply bleached yarn (Tables VII and VIII) is more than double that of the 24/3 ply brown mercerized yarn (Table I). This is reasonable, considering the relative weights of the two yarns. The average ranges, and therefore the standard deviations of samples of fours, are

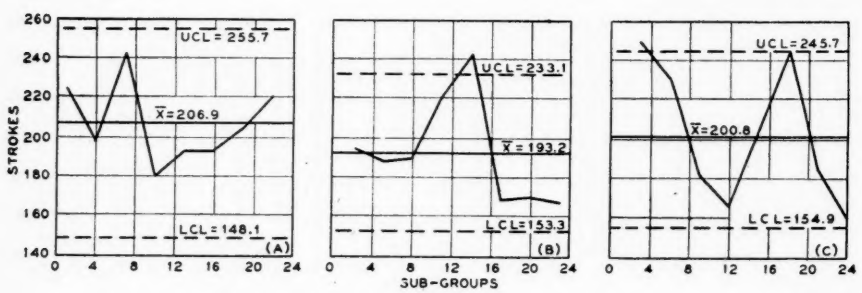

FIG. 12. *Control charts of abrasion resistance. Single strands—10/3 ply bleached cotton. Average of four taken every third specimen along yarn length. A—Beginning with first specimen. B—Beginning with second specimen. C—Beginning with third specimen. Data in Table X.*

TABLE X. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—10/3 BLEACHED YARN *
Sub-group averages of samples of four based on every third observation
Data previously listed in Table VIII •

A				B				C			
Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	229			6	229			2	276		
7	206			13	167			11	261		
14	219		38	12	206		62	4	275		88
8	244	225		15	178	195		5	188	250	
9	179			16	199			3	276		
1	172			10	181			15	218		
3	235		63	16	184		18	2	171		105
5	206	198		9	187	188		12	254	230	
8	257			11	208			1	193		
14	275			17	192			13	170		
4	235		75	6	160		48	10	146		68
7	200	242		14	199	190		4	214	181	
16	161			10	173			7	154		
3	178			11	220			2	169		
17	184		34	9	227		96	6	138		63
13	195	180		8	269	222		1	201	166	
5	135			12	244			15	189		
16	241			3	307			15	219		
9	189		106	12	223		109	2	214		30
4	205	193		10	198	243		13	199	205	
17	217			6	159			8	221		
5	203			11	176			14	217		
7	208		72	1	159		26	10	213		68
4	145	193		2	183	169		14	281	233	
5	187			15	198			17	202		
8	233			6	161			16	193		
9	200		46	7	141		57	13	173		37
11	199	205		1	184	171		3	165	183	
12	270			14	179			8	161		
6	241			2	170			15	147		
11	205		102	5	157		22	13	148		34
10	168	221		4	164	168		7	181	159	
16	237			12	150			1	144		
17	267			3	180			9	197		
$\bar{X}$ = 206.9					193.2				200.8		
$\bar{R}$ = 67.0					54.8				61.6		
UCL = 255.7					233.1				245.7		
LCL = 148.1					153.3				154.9		

* See Table I for nomenclature.

in essentially the same ratio. This suggests that, since the ratio of the average range to the average is almost the same for the two types of cotton, and these results are typical of other data, the variability of the cotton may be defined by such a ratio for comparative purposes.

It may reasonably be concluded from these considerations that the wearing qualities of these two yarns are nearly alike, after taking account of the difference in weight. No doubt many factors contribute to the wearing quality of any given yarn, such as fiber length and diameter, twist, ply, and chemical

treatments applied to the material. For example, a cheaper grade of cotton than the two just compared, the 24/3 ply red cotton of Tables V and VI, is seen to have a higher abrasion resistance than the mercerized yarn of the same count, and on a comparable weight basis it wears longer than the 10/3 ply yarn. The soda-boil treatment used prior to the dyeing of the 24/3 ply red cotton is considered to be less drastic chemically than either the bleaching or the mercerizing treatments, but the only purpose of this discussion is to point out that such differences may be examined with profit by means of the abrasion test on yarns.

7. Effect of Textile Finishing Processes. Some of the 24/3 ply red dyed cotton was subjected to a commercial finishing treatment consisting of the application of a starch glaze. Aside from improving the appearance of the yarn by imparting a polish, such a finish might reasonably be expected to have the additional function of improving the wearing quality of the textile. However, yarn abrasion tests indicate that this desirable objective is but indifferently achieved. In Figure 14, a control chart based on data in Table XI for this glazed yarn, the average is 142. This is somewhat lower than the average for the untreated yarn, which was above 150 (Tables V and VI). The range of averages of four is essentially the same for both the untreated and the glazed samples of this yarn, and in both cases there is evidence of lack of control. Certainly, one objective of a finishing treatment such as this might be to improve, if possible, the uniformity of a textile, and

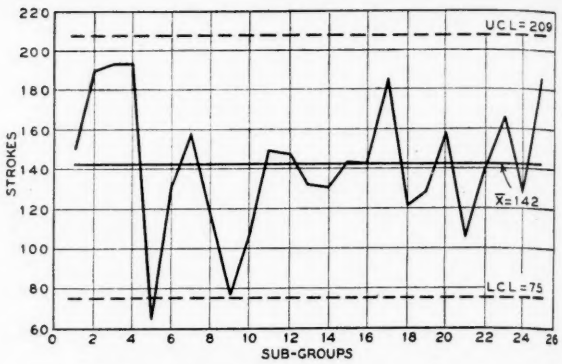

FIG. 14. *Control chart of abrasion resistance. Single strands—24/3 ply red glazed cotton. Averages of four taken consecutively along yarn length. Data in Table XI.*

these data emphasize the fact that this possibility could be investigated to advantage by means of the abrasion test and suitable statistical procedure.

Some of this yarn was glazed experimentally in laboratory equipment provided with controls so that the results might be expected to be somewhat better than in commercial practice. The data for this glazed yarn are given in Table XII. The control chart is Figure 15. The grand average is higher for the treated than for the untreated yarn—190 as compared with a value between 150 and 160. The treatment did not, however, result in control, for one sub-group average is outside the control limit. The average range for samples of fours is 140 as compared with 76 for the untreated material, indicating variability out of proportion to the degree of improvement in average abrasion resistance.

Double strand tests on this 24/3 ply red untreated cotton averaged 1,648 strokes (Table XIII and Fig-

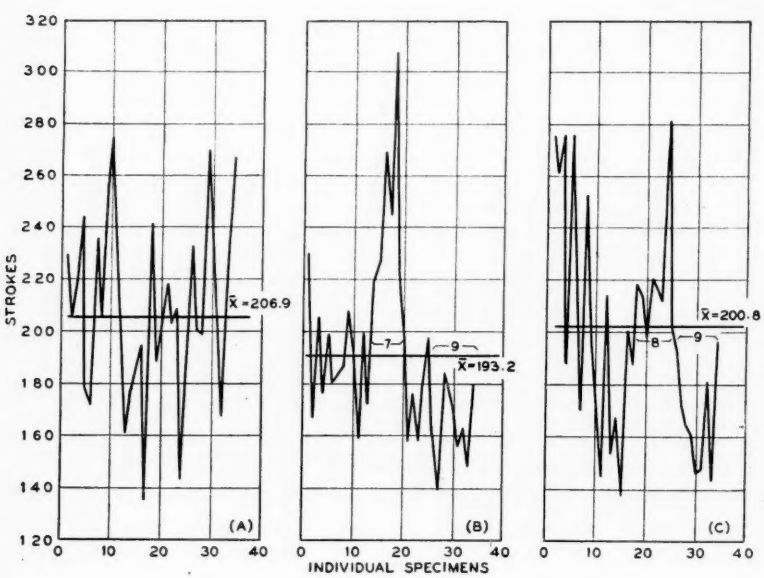

FIG. 13. *Abrasion resistance charts of individual specimens. Single strands —10/3 ply bleached cotton. Each chart made up of every third specimen along yarn length. A—Beginning with first specimen. B—Beginning with second specimen. C—Beginning with third specimen. Data in Table X.*

TABLE XI. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—24/3 PLY RED GLAZED YARN *
Data listed in order of selection from skein
Skein-conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	186			16	124			5	89		
6	120			10	121			15	203		
2	129		66	7	82		42	17	115		114
7	164	150		3	117	111		8	110	129	
13	226			11	215			6	206		
11	153			2	126			16	157		
14	227		74	17	140		97	9	127		79
12	154	190		9	118	150		7	143	158	
4	176			6	219			13	142		
8	153			13	78			11	67		
15	293		145	8	118		141	1	86		75
5	148	193		1	176	148		3	127	106	
9	230			5	168			12	121		
16	191			12	150			14	150		
3	166		64	15	115		72	8	132		38
1	183	193		16	96	132		6	159	141	
10	80			3	180			2	165		
15	68			15	126			15	101		
3	64		25	9	124		87	11	165		130
16	55	67		12	93	131		5	231	166	
2	155			2	176			13	159		
5	130			4	129			10	182		
9	117		43	10	133		47	4	77		105
12	112	130		13	138	144		7	104	131	
8	140			17	122			16	134		
11	207			6	122			12	174		
1	171		93	8	138		68	1	253		119
14	114	158		5	190	143		17	182	186	
17	168			11	339			3	261		
13	52			14	212			9	151		
4	184		132	7	102		248				
6	74	120		1	91	186					
10	86			10	219			$\bar{X}$ = 142			
7	86			4	90			$\bar{R}$ = 92			
14	92		48	2	70		149	UCL = 209			
4	44	77		14	104	121		LCL = 75			

* See Table I for nomenclature.

ure 16), as compared with 157 strokes for the single strands. Application of the experimental glaze raised the average to 3,381 strokes for double strands (Table XIV and Figure 17), as compared with 190 for single strands. These results illustrate the fact that greater improvement in wear resistance is indicated by double than by single strand tests. It will be seen from these charts (Figures 16 and 17) that all averages for double strands are within control limits, whereas some for single strand tests are outside limits. This apparent anomaly may be attributed in part to an inordinate increase in the average range, coupled with the averaging of two sections of yarn, when using double strands. The latter consideration may also explain the greater degree of improvement observed for finished yarn when the double strands are used. There are as yet insufficient data to explain these results adequately, but it is probable that the explanation can be obtained through a systematic investigation because

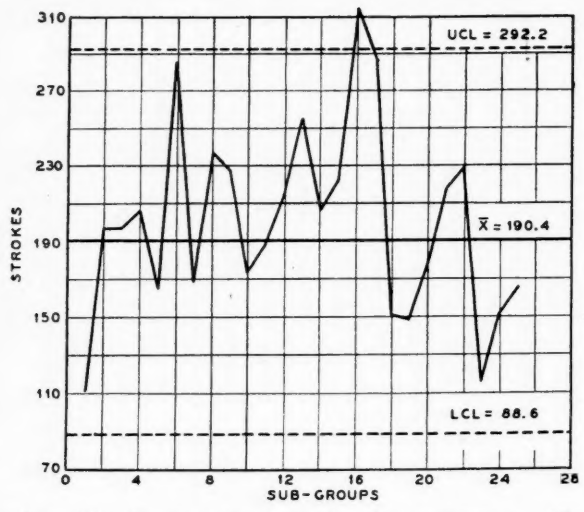

FIG. 15. *Control chart of abrasion resistance. Single strands—24/3 ply red glazed cotton—lot 4. Averages of four taken consecutively along yarn length. Data in Table XII.*

the data obtained with the yarn abrasion test appear to be consistent within themselves.

Because of the evident improvement in wearing quality afforded by this experimental finish, it was considered important to check this result. Accordingly, a second lot of the same 24/3 ply red dyed yarn was sent to the same laboratory to be treated with the same starch finish. The results presented in Table XV and Figure 18 show that this second lot is actually lower in average than the untreated material, and that there is evidence of lack of control, even on double strand tests. It has since been ascertained that the processing conditions were not alike in these two experimental runs, and these control charts show that it is possible to detect such differences readily by means of the abrasion test.

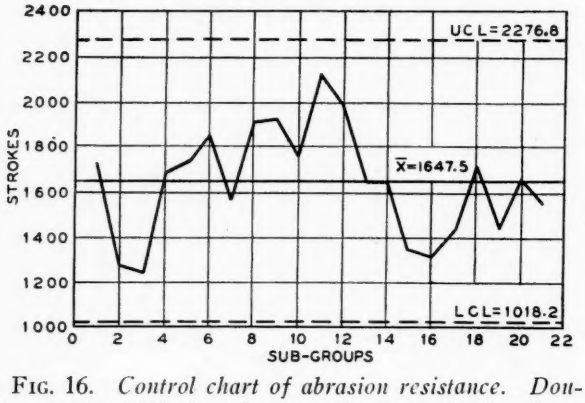

FIG. 16. *Control chart of abrasion resistance. Double strands—24/3 ply red untreated cotton—lot 0. Averages of four taken consecutively along yarn length. Data in Table XIII.*

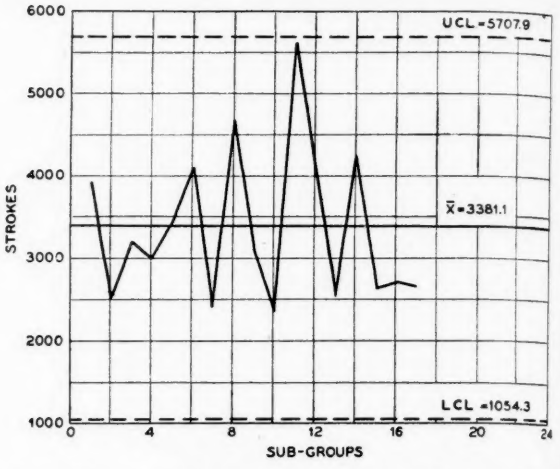

FIG. 17. *Control chart of abrasion resistance. Double strands—24/3 ply red glazed cotton—lot 4. Averages of four taken consecutively along yarn length. Data in Table XIV.*

Wide variations are found in the quality of yarns which have been glazed commercially. For example, single strand tests made on two packages of such yarn which had been put through a slasher at the same time gave the following results: One package had an average abrasion resistance of 187, with control limits for averages of four located at ±92 relative to the average. The other package had an average of 278, with corresponding limits of ±135.

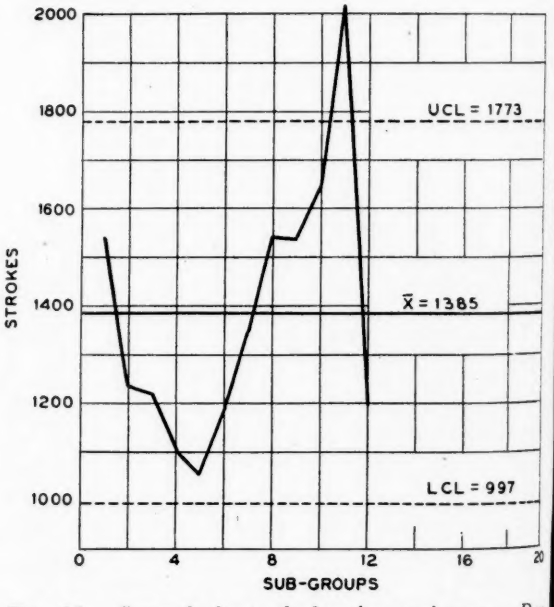

FIG. 18. *Control chart of abrasion resistance. Double strands—24/3 ply red glazed cotton—lot 6. Averages of four taken consecutively along yarn length. Data in Table XV.*

TABLE XII. ABRASION RESISTANCE OF SINGLE COTTON STRANDS—24/3 PLY RED GLAZED YARN—LOT 4*

Data listed in order of selection from skein
Skein-conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	84			17	218			2	334			12	252		
6	115			13	212			4	247			14	294		
2	104		51	4	275		63	10	155		188	8	239		161
7	135	110		6	248	238		13	146	221		6	133	230	
13	251			10	265			17	320			2	74		
11	72			7	248			6	465			15	119		
14	236		179	14	224		86	8	232		233	11	148		74
12	227	197		4	179	229		5	241	315		5	120	115	
4	116			16	169			11	403			13	104		
8	216			10	140			14	225			10	180		
15	347		231	7	217		77	7	231		178	4	186		82
5	110	197		3	161	172		1	292	288		7	136	152	
9	144			11	146			10	141			16	226		
16	352			2	149			4	156			12	153		
3	160		208	17	272		126	2	155		15	1	109		117
1	171	207		9	179	187		14	148	150		17	176	166	
10	174			6	180			5	89			3	240		
15	100			13	290			15	104			9	260		
3	243		143	8	86		224	17	271		182				
16	137	164		1	310	217		8	129	148					
2	155			5	225			6	181						
5	359			12	204			16	133						
9	186		292	15	261		126	9	225		92	$\bar{X}$ = 190.4			
12	447	287		16	330	255		7	170	177		$\bar{R}$ = 139.6			
												UCL = 292.2			
8	139			3	272			13	218			LCL = 88.6			
11	184			15	255			11	207						
1	129		92	9	189		164	1	166		116				
14	221	168		12	108	206		3	282	218					

*See Table I for nomenclature.

In both cases sub-group averages of fours were found outside these limits.

Specific Properties of Textile Yarns Related to Wear

The colors of the several yarns enumerated in this discussion have no significance other than that of identification. It is, of course, possible that in certain cases the dye process may have an effect that is detectable by this test. In addition, chemical processes may affect the wearing quality of textiles and this property may be affected also by twist and other yarn characteristics. Some interesting possibilities for quantitative evaluation are indicated by the examples given in this paper.

It should be emphasized that although tests made on yarns may not give an exact measure of the wearing quality of a finished material, it is considered likely that yarns taken from a piece of finished goods should yield valuable information concerning the wearing quality of the goods. It may be remarked that a few tests on strands unraveled from silk stockings did give illuminating information regarding the finishing treatments to which they had been subjected. Conversely, abrasion tests on yarns treated with the finishing or chemical processes normally applied to cloth should be useful in indicating means of securing better control of the cloth treatment.

Value of Statistical Quality Control Techniques

1. *Applied to Manufacturing Processes.* The value of statistical quality control techniques as tools for the control of manufacturing processes is being attested daily by the steady increase in the number of

TABLE XIII. ABRASION RESISTANCE OF DOUBLE COTTON STRANDS—24/3 PLY RED UNTREATED YARN—LOT 0*

(Same material as used in Tables V and VI)
Data listed in order of selection from package
Package conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	1,730			17	1,439			2	1,222		
6	1,340			13	1,884			4	1,315		
2	1,750		745	4	2,567		1,128	10	941		997
7	2,085	1,726		6	1,749	1,910		13	1,938	1,354	
13	1,618			10	1,512			17	1,564		
11	1,540			7	1,663			6	1,039		
14	1,080		739	14	2,252		801	8	860		992
12	879	1,279		4	2,313	1,935		5	1,852	1,329	
4	1,574			16	1,898			11	1,813		
8	1,680			10	1,829			14	926		
15	958		886	7	1,490		408	7	1,840		914
5	794	1,252		3	1,761	1,745		1	1,158	1,434	
9	2,034			11	2,565			10	1,827		
16	1,699			2	1,807			4	1,819		
3	1,503		531	17	2,173		758	2	1,710		337
1	1,505	1,685		9	1,979	2,131		14	1,490	1,712	
10	1,518			6	1,982			5	1,438		
15	2,018			13	2,064			15	1,143		
3	1,928		532	8	1,575		789	17	1,778		635
16	1,478	1,734		1	2,364	1,996		8	1,429	1,447	
2	2,011			5	2,043			6	1,349		
5	1,996			12	1,865			16	1,785		
9	1,035		1,343	15	1,344		699	9	2,139		790
12	2,378	1,855		16	1,371	1,656		7	1,362	1,659	
8	1,508			3	930			13	1,220		
11	2,073			15	1,708			11	1,494		
1	815		1,258	9	1,657		1,338	1	1,005		1,510
14	1,842	1,560		12	2,268	1,641		3	2,515	1,559	

$\bar{X}$ = 1,647.5 UCL = 2,276.8
$\bar{R}$ = 863.3 LCL = 1,018.2

* See Table I for nomenclature.

published articles and by increased attendance at lectures and courses dealing with them. In essence, this method has been defined as a "system of production control through sampling inspection, based on the fact that if a process is steady it is possible to predict results within defined limits, and the trespass of results beyond these limits is a definite sign of impending trouble."[9] For instance, a production process may be judged to be controlled when the averages of at least twenty-five consecutive samples of fours are within statistically defined quality control limits [4]. Experience has shown that occurrence of an average outside statistical control limits is often sufficient evidence that trouble is present in the process. This does not mean that every case of trouble will give an indication in the first sample after trouble starts, nor does it mean that trouble is invariably indicated by a sample with an average outside the control limits. These limits are chosen, in light of experience, to indicate difficulties that have sufficient economic justification to make it worth while to identify and correct them if practicable. Thus minor variations may not be considered troubles at all but may be accepted as part of the permissible variation. In production, the possible causes of trouble and their effects are usually quite well known because they have been encountered during development or the early stages of manufacture. Hence, the quality control signals are all that

[9] Quoted from a circular giving information regarding a quality control lecture course at Birmingham, England, June 23, 1944.

TABLE XIV. ABRASION RESISTANCE OF DOUBLE COTTON STRANDS—24/3 PLY RED GLAZED YARN—LOT 4 *
Data listed in order of selection from package
Package conditioned and tested at 65% R.H.—70°F

Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4	Pin No.	Strokes at break	$\bar{X}_4$	R_4
17	2,830			17	4,257			2	3,548		
6	3,836			13	1,557			4	2,825		
2	2,435		4,180	4	5,944		5,321	10	2,518		1,794
7	6,615	3,929		6	6,878	4,695		13	1,754	2,639	
13	3,179			10	2,768			17	3,424		
11	1,276			7	6,332			6	2,912		
14	2,752		1,903	14	2,551		5,428	8	1,281		2,143
12	2,948	2,539		4	904	3,139		5	3,238	2,714	
4	5,006			16	1,555			11	2,502		
8	3,126			10	1,571			14	7,165		
15	2,635		2,972	7	2,250		2,678	7	3,602		5,767
5	2,034	3,200		3	4,233	2,402		1	1,398	2,667	
9	6,572			11	2,520						
16	2,215			2	4,707						
3	2,202		5,556	17	8,432		5,912				
1	1,016	3,001		9	6,786	5,611					
10	3,488			6	5,918						
15	3,755			13	4,404			$\bar{X}$ = 3,381.1			
3	4,781		3,006	8	3,302		2,670	$\bar{R}$ = 3,233			
16	1,775	3,550		1	3,248	4,218		UCL = 5,707.9			
								LCL = 1,054.3			
2	4,167			5	2,730						
5	3,804			12	2,319						
9	2,898		2,647	15	2,987		852				
12	5,545	4,104		16	2,135	2,543					
8	1,950			3	3,252						
11	2,445			15	3,314						
1	2,778		828	9	2,567		1,303				
14	2,484	2,414		12	3,870	4,251					

* See Table I for nomenclature.

are necessary to justify an intensive search for the guilty factor.

2. *Applied to Research.* In research, the situation may be different. The likely causes are often unknown. Thus, when an average is found to be outside limits, although it is desirable to find the cause, this may be particularly difficult because there may be only a limited number of observations for which the associated qualitative information is incomplete. Sometimes too few measurements are available to provide adequate evidence for control, or even to show that control does not exist. It is therefore reasonable to question whether or not there are means for identifying changes in level, trends, cycles, etc., that may occur in research data. If such means are available it is obviously worth while to determine their possible usefulness when the usual quality control technique does not indicate that "trouble" is present, in the same sense in which the term is used above.

In the examples given here, it is seen that the control chart detects almost all cases of trouble—certainly all that would be of major interest to the production engineer. From the viewpoint of research, additional information is provided by the run chart with its indication of definite changes in level. No statistical test based on a mathematical model has yet been devised for a trend in a partial set of data, so that the best statement that can be made is that between two portions of the set a change in level has occurred. It is also true that tests for cycles assume elimination of trends. But without a measure of this kind, the use of such tests may be questionable. Nevertheless, one case of an apparent cycle has been investigated for its theoretical interest, and as a result of the serial correlation which

TABLE XV. ABRASION RESISTANCE OF DOUBLE COTTON STRANDS—24/3 PLY RED GLAZED YARN—LOT 6 *
(REPEAT OF PROCESS USED FOR LOT 4)

Data listed in order of selection from package
Package-conditioned and tested at 65% R.H.—70°F

Pin	Strokes	$\bar{X}_4$	R_4	Pin	Strokes	$\bar{X}_4$	R_4
17	1,531			17	1,491		
6	1,593			13	1,531		
2	1,453		140	4	1,550		100
7	1,591	1,542		6	1,591	1,541	
13	1,233			10	1,593		
11	1,423			7	1,702		
14	723		827	14	1,606		451
12	1,550	1,232		4	1,251	1,538	
4	1,193			16	1,633		
8	1,193			10	1,607		
15	994		497	7	1,492		356
5	1,491	1,219		3	1,848	1,645	
9	1,270			11	2,727		
16	1,175			2	1,231		
3	800		470	17	2,207		1,496
1	1,173	1,105		9	1,900	2,016	
10	1,702			6	1,529		
15	723			13	1,277		
3	900		979	8	1,270		816
16	994	1,055		1	713	1,197	
2	1,173			5	1,497		
5	1,175			12	1,702		
9	1,193		24	15	1,678		
12	1,197	1,185					
8	1,233			$\bar{X}$ = 1,385			
11	1,270			$\bar{R}$ = 532.1			
1	1,423		230	UCL = 1,773			
14	1,453	1,345		LCL = 997			

* See Table I for nomenclature.

suggested a cycle of approximately three, a further set of control charts were plotted on this hypothesis and the results show evidence of lack of control, whereas the original chart did not give such evidence.

Conclusions

The yarn abrasion test described here has been shown to be capable of giving statistically controlled data. It has been used effectively in evaluating the performance of braided structures. It has also been demonstrated that the apparatus measures difference in quality of finishes applied to yarns, and it is concluded that similar experiments made on the application to yarns of treatments that are normally used on finished goods should go far in assisting to establish the optimum conditions for applying these treatments on cloth.

Because of these findings, it is considered eminently reasonable to recommend this method of test as a valuable adjunct in any textile investigation, whether as a research tool or as a quality control inspection method in an industrial process. The methods of analysis discussed in connection with these data are important not only for assessing the value of this particular tool, but also by example, in suggesting the possible utility of these analyses to other methods of test, whether in the textile industry or elsewhere.

Summary

Specifically these thoughts may be summarized as follows:

1. The yarn abrasion test described in this paper is shown to be a valuable new tool for use in textile manufacturing control and research study.

2. Control charts obtained with such yarn tests may be used profitably for manufacturing control.

3. Control, run, and lag correlation charts are shown by example to possess valuable possibilities for use in discovering and identifying changes in level, trends, cycles, etc., in development work for the manufacturing processes used for textiles.

4. There are many tests, some of which are not used in the textile industry, which have been considered of limited value because of the wide variability in consecutive measurements. The principles illustrated here offer a practical basis for determining reproducibility in such tests as corrosion, Izod impact, tensile strength, elongation, etc., and for establishing causes of variability.

5. Successful application of these principles depends upon close cooperation of the engineer and the statistician, where each contributes to the working out of a joint solution, making use of the technical skills of both.

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Fabric Deterioration by Thirteen Described and Three New Species of Chaetomium

Glenn A. Greathouse[1] and L. M. Ames[2]

THE loss of military material, mainly cotton fabrics, paper packages, and other cellulosic substances, in tropical and subtropical areas has directed renewed attention to and stimulated studies concerning cellulose-decomposing organisms, among which species of the genus *Chaetomium* are conspicuous.

For many years species of *Chaetomium* have been listed among cellulose destroyers. However, few studies have been made to determine the importance of species other than *C. globosum Kunze* in the deterioration of cellulose materials.

Comparative information relating to *Chaetomium globosum* and other *Chaetomium* species should be of special interest to textile workers at this time since *C. globosum* is so commonly referred to in Government specifications and in commercial laboratories where it is used as a test organism for the evaluation of fabrics treated with fungicides.

Evidence is presented in this paper which establishes the comparative abilities under similar experimental conditions of sixteen species of *Chaetomium* to decompose cotton fabric. Drawings of most of the species are included in Figure 1. Approximately one-half of the known species of *Chaetomium* are included in this study.

A brief review of the literature and a table, giving the source of the organisms studied, and persons contributing them and responsible for their identification, have been presented [1].

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[2] Mycologist, U. S. Army, Corps of Engineers, Ft. Belvoir, Virginia.

The original manuscript by this title was published in *Mycologia* **37**: No. 1, 138–55, 1945. That report included the Latin description and the original drawings of three new *Chaetomium* species. However, this paper contains information of interest to textile as well as mycological investigators. Since probably few workers in the textile field subscribe to *Mycologia* it is the Editor's thought that a brief presentation of data and drawings of *Chaetomium* species would be useful to textile personnel interested in our present fabric and cordage problems.

Materials and Methods

Bleached, 8-ounce Army duck, with an original breaking strength of 140.5 pounds, was used throughout the investigations. Before exposure to the attack of fungi, the fabric was treated to remove sizing, waxes, pectins, and other substances that might serve as added nutrients.

The "glass-wick" procedure and the basic nutrient medium designated as Formula A, described by Greathouse, Klemme, and Barker [2], was used. The nitrogen source of this formula was varied by substituting equivalent amounts of nitrogen as $NaNO_3$, $(NH_4)_2SO_4$, or $NH_4H_2PO_4$ for NH_4NO_3.

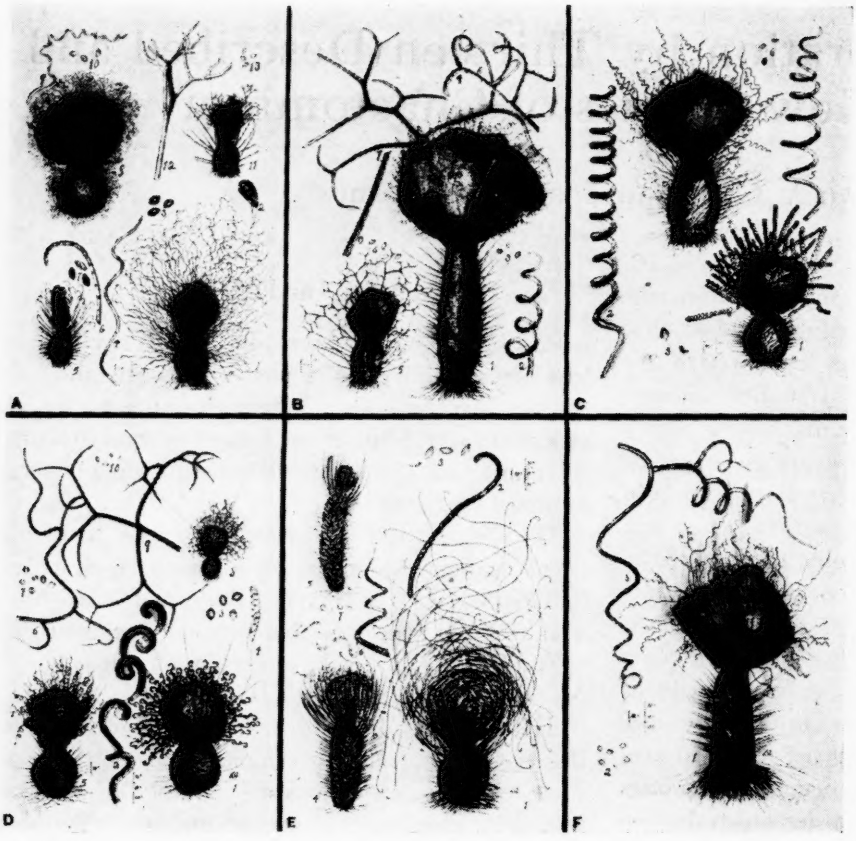
The fabric used was divided into large blocks so that each block would furnish one of the ten replicates used for each determination. The blocks were cut into strips measuring 15 cm. (6 inches) in the warp direction by 3.1 cm. (1.25 inches), and by raveling the width was reduced to exactly 2.5 cm. (1 inch).

The inoculated strips of fabric were incubated for a 7-day period in a darkened, air-conditioned room which was maintained at 85° to 86° F. (20.4 to 30° C) and 90 to 94 percent relative humidity. All results are based on the average change of breaking strength of ten strips subjected to individual inoculations.

The final strength of the test fabric after incubation with the fungus was recorded in pounds and calculated as the percentage of the original breaking strength. Comparative results of the tests are given in Table I.

Results

The results presented in Table I show that the *Chaetomium* species vary in their ability to decompose cellulose and in their reaction to different nitrogen sources. It also may be observed that variations exist between several isolates of some species. On the basis of results obtained an arbitrary classification into physiological groups has been made for convenience of discussion. Information concerning



these groups is based upon the conditions of these tests, such as the use of four nitrogen sources and an incubation period of 7 days.

FIG. 1.

A—1–4, Chaetomium globosum; 5–7, Chaetomium aureum; 8–10, Chaetomium ochraceum; 11–13, Chaetomium funicolum.
B—1–3, Chaetomium caprinum; 4–7, Chaetomium elatum.
C—1–3, Chaetomium aterrimum; 4–6, Chaetomium cochliodes.
D—1–4, Chaetomium contortum; 5–7, Chaetomium bostrychodes; 8–10, Chaetomium dolichotrichum.
E—1–3, Chaetomium murorum; 4–7, Chaetomium microcephalum.
F—1–3, Chaetomium pachypodiodes.

TABLE I. EFFECT OF DIFFERENT SPECIES OF *Chaetomium*, GROWN ON FOUR NITROGEN SOURCES, ON THE BREAKING STRENGTH OF 8-OUNCE COTTON DUCK, AFTER 7 DAYS' INCUBATION

Species	Isolate number	Residual breaking strength as percent of the original				Physiological groups
		$NaNO_3$	NH_4NO_3	$(NH_4)_2SO_4$	$NH_4H_2PO_4$	
C. globosum	1042.4	7.6	13.9	21.2	24.1	I
C. globosum	1042.5	9.1	11.4	20.2	28.8	I
C. globosum	1042.6	18.6	11.6	23.3	27.4	I
C. globosum	1042.7	18.6	19.1	20.0	25.2	I
C. caprinum	1043.0	10.8	10.1	15.8	33.6	I
C. cancroideum	1044.4	25.2	10.6	26.0	21.4	II
C. dolichotrichum	1044.7	37.0	19.6	20.9	20.0	III
C. funicolum	1043.1	49.7	21.9	20.9	18.0	III
C. funicolum	1043.2	48.2	15.3	19.9	13.6	III
C. elatum	1043.4	45.0	28.6	28.5	32.9	III
C. elatum	1043.5	47.9	22.6	19.6	34.5	III
C. contortum	1044.9	34.8	25.2	28.7	27.5	III
C. bostrychodes	1045.1	22.9	20.2	23.9	23.9	IV
C. cochliodes	1043.6	44.3	51.3	54.7	55.0	IV
C. cochliodes	1043.7	54.9	43.4	48.0	61.9	IV
C. murorum	1044.8	43.7	45.2	46.7	48.9	IV
C. orchraceum	1044.5	44.4	54.1	54.4	55.6	IV
C. aterrimum	1043.8	50.9	45.9	44.5	45.3	IV
C. aureum	1043.9	50.5	45.5	60.6	62.1	IV
C. pachypodiodes	1044.3	74.9	70.3	38.4	33.1	V
C. convolutum	1044.0	89.6	87.9	89.9	82.7	VI
C. microcephalum	1045.0	91.3	54.0	100.0	100.0	VII
pH of original autoclaved medium		7.1	6.6	5.8	5.5	
pH of medium at harvest		6.7–8.4	5.8–6.6	4.6–5.8	4.3–5.5	

Group I includes *C. globosum* and *C. caprinum,* very active cellulose decomposers, which produce slightly greater losses in breaking strength on a nitrogen source, such as $NaNO_3$. The pH of the medium containing this nitrogen source ranges on the alkaline side of neutrality following the utilization of the NO_3 radical by the fungus.

Group II is represented by *C. cancroideum,* a rapid cellulose decomposer, which seems to be most active on a neutral to slightly acid medium, NH_4NO_3. This species is morphologically similar to *C. funicolum.*

Group III contains *C. dolichotrichum, C. funicolum, C. elatum,* and *C. contortum,* which are active cellulose destroyers that thrive especially well on the more acid nitrogen sources, NH_4NO_3, $(NH_4)_2SO_4$, and $NH_4H_2PO_4$.

Group IV is characterized by species that are active to moderately active in destroying cellulose and that have no marked preference for nitrogen sources.

Group V, typified by *C. pachypodiodes,* is restricted in its preference of nitrogen source to $(NH_4)_2SO_4$ and $NH_4H_2PO_4$.

Group VI, represented by *C. convolutum,* is a relatively inactive cellulose decomposer.

Group VII is exemplified by *C. microcephalum.* It seems to be restricted in its ability to decompose cellulose under these experimental conditions to a very narrow limit, i.e., NH_4NO_3 medium.

Three of the sixteen species of *Chaetomium* tested were described as new; namely, *C. dolichotrichum, C. microcephalum,* and *C. pachypodiodes.* Several other isolates of *Chaetomium* were studied and found to be inactive as cellulose decomposers. It is not an unusual phenomenon among genera of fungi to find that certain species are very active cellulose decomposers whereas others cannot utilize cellulose as their carbon source.

C. globosum, the fungus chosen as the test organism by Thom *et al.* [3], is characteristic of the genus *Chaetomium* in decomposing cellulose, with the possible exception that it thrives best in a slightly alkaline medium. The organism to be used in testing fabrics for mildew-resistance should be capable of rapidly destroying cellulose and be stable in its cultural and cellulose-destroying characteristics. Its response to specific factors—i.e., pH, temperature, fabric preservative, etc.—should have been established. Also its distribution and occurrence in nature should be known. *C. globosum,* as well as several other *Chaetomium* species, meets the majority of these requirements.

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3. Thom, Chas., Humfeld, H., and Holman, H. P., Laboratory Tests for Mildew-Resistance of Outdoor Cotton Fabrics. *Am. Dyestuff Rptr.* **23**, 581–6 (1934).

ABSTRACTS

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ANALYSIS: TESTING: LABORATORY METHODS

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Determination of Formaldehyde

The determination of CH_2O in swelling-resistant fibers. W. Weltzien. *Zellwolle, Kunstseide, Seide* **47**, 197–200 (1942); *Chem. Zentr.* **II**, 1196 (1942) (through *Chem. Abstr.* **39**, 1762[9], Apr. 20, 1945).

The method of Tobel and Vogel (*C.A.* **38**, 2503[1]) is reliable but time-consuming. Wurtzschmitt's modified hydroxylamine method is suggested as a standard method. Heat 4 g. of sample (dried at 105°) with 50 cc. H_2O and 10 cc. *N* HCl in a pressure bottle for 15 minutes at 55–60° and for 1 hour at 110°; cool, add 40 cc. water, and filter through a dry filter. Treat 75 cc. of the filtrate with 6 cc. *N* NaOH and neutralize with 0.1 *N* NaOH. Add 10 cc. of approximately *N* $NH_2OH \cdot HCl$ solution, close the bottle, let stand 10 minutes, and titrate the mixture with 0.1 *N* NaOH. Dilute 10 cc. of $NH_2OH \cdot HCl$ with 90 cc. H_2O and titrate with 0.1 *N* NaOH. The percentage content of CH_2O in the dried fabric is $0.4\ (b-c)/a$, where $a=4$, and b and c are the numbers of cc. of 0.1 *N* NaOH used in the first and second titrations, respectively. Possible sources of errors in this method are the presence of polymeric and loosely bound CH_2O, as in urea-HCHO finishes.

Determination of Naphtol AS Series

A method for the determination of members of the brenthol or naphtol AS series by ultraviolet absorption. C. H. Giles. *J. Soc. Dyers and Colourists* **61**, 47–9 (Feb. 1945).

A reliable means of determining members of the brenthol series (arylamides of 2-hydroxy-3-naphthoic acid and related compounds) in solution has been devised, employing the Spekker absorptiometer with ultraviolet illumination. The method is simpler and gives more accurate results than the method in which azo- solutions and visible light are employed. The substantivity of brenthol AT for cotton, linen, and vicose rayon has been determined by the new method.

Author

Fiber Identification

Identification of new fibers and chemicals in rag cuttings. F. L. Simons. *Paper Mill News* **67**, No. 51, 14, 16, 18 (1944) (through *Chem. Abstr.* **39**, 1989[8], May 10, 1945).

An outline of a few of the quicker and simpler methods of identifying synthetic fibers and fabrics with particular reference to tests that are suitable for use in the rag room. A flame test and a solubility test with Me_2CO containing 30–50% PhOH are usually sufficient to show definitely whether a fabric is or is not cotton, and consequently suitable for paper-making. Regenerated fibers (viscose and cuprammonium rayon) can be tested for by means of "Texchrome," a proprietary product related to Neocarmine. Identification of special waterproofing treatments or other chemicals on or in rags for use in paper-making is a much more complex matter than identification of fibers; the presence of an appreciable quantity of such materials can probably be detected in the rag room by the appearance or "handle" of the rags, but their actual identification is almost impossible.

Identification of Resins

Identification of melamine and urea resins in wet strength paper. R. W. Stafford, W. M. Thomas, E. F. Williams, and N. T. Woodberry. *Paper Trade J.* **120**, 51–6 (Apr. 19, 1945).

The details of two new laboratory methods for the identification of melamine and urea resins in wet strength paper are reported. The first procedure involves a dye-staining test for melamine, which in some cases is also applicable to urea resins and proteins. The second procedure describes an optical method for the specific identification of urea after hydrolysis of the resin and precipitation with xanthydrol. Reported procedures for the detection and identification of

protein wet strength additives as well as general methods for resins in paper are listed and discussed. All the various techniques have been arranged in a convenient order, according to applicability and time requirements. Authors

Micro Spinning-Test

Uses and accuracy of cotton spinning-tests on 60-gram samples. H. A. Hancock. *J. Text. Inst.* **36**, T10–18 (Jan. 1945).

A technique for spinning 60-gram samples on standard cotton machinery is described. The sources of variation in this two-ounce "micro spinning-test" are analyzed into those arising from (*a*) real differences between the cotton under test, (*b*) spinning machine errors, and (*c*) variations due to imperfect sampling of the cotton. Purely spinning errors are shown to be surprisingly little affected by reducing the sample weight from a kilogram down to 60 grams. Numerical estimates are given for the unwanted errors, and for their relation to the genetic variances involved, in a few cases of general interest. Although designed primarily for its economy in cotton, a fourfold increase in speed of working turned out to be as great an asset of the microtest. It is in fact used mainly for its advantage in speed on samples of which there is enough cotton for a full-scale spinning. In such cases the sampling error can be made negligible, because 60 grams can be representative of a much larger bulk. Direct answer by the spinning-test now supersedes the need for inferences based on lint measurements. An important application of the test is to commercial crop control and the elimination of deteriorated or contaminated seed. All seed-cotton intended for sowing seed in the following crop is required by Egyptian law to be tested in advance. For the long staple varieties, acceptance or refusal of the lots for sowing is now on the basis of lint quality. Spinnings are carried out at the Government station on mass production lines, and the method is believed to mark a big advance in crop control for quality. All the long staple cotton of Egypt is now grown directly from seed whose lint has passed the spinning standards, lot by lot. Author

Service Testing

Service testing of textile materials. J. Labarthe, Jr. *Am. Dyestuff Reptr.* **33**, P482–4 (Nov. 20, 1944).

The controlled and carefully observed use test which is becoming well developed due to necessity in Army procurement is discussed and its applicability in testing civilian goods noted. The failure of conventional standard test procedures to answer practical questions of the consumer is evident, and it is believed that new testing techniques will aid in evaluating consumer goods as to durability and adequacy for intended use. Author

CHEMICAL AND PHYSICAL RESEARCH

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Acetylation of Cellulose

The structure of cellulosic rayons. Part 1. The non-degradative acetylation and deacetylation of cellulose and secondary cellulose acetate. Frank Howlett. *J. Text. Inst.* **35**, T123–32 (Nov. 1944).

The present paper is intended to be the first of a series describing an experimental study of the structure of cellulosic rayons, with particular reference to the chain length (degree of polymerization) and chain length distribution of their molecules. Cellulose acetate rayons were the first to be examined, and difficulties soon arose owing to the fact that many of them differed slightly in acetic acid yield. It, therefore, became important to have available methods that could be used to change the degree of acetylation of a cellulose acetate without changing its degree of polymerization, i.e., without causing any degradation. The use of such methods would enable materials of slightly different acetic acid yield to be compared with greater accuracy, either by bringing them all to the same acetic acid yield, or by studying the behavior of a series of samples differing only in acetic acid yield, so that its effect could be eliminated from the comparison. With the extension of the work to the regenerated cellulose rayons the need for such methods became even more imperative, because it proved impracticable to use solutions of cellulose in the ordinary cellulose solvents for all the purposes of the investigation, and conversion to acetate by a non-degradative process would permit the application of methods similar to those developed for acetate rayon. In the present paper several factors affecting the acetylation of secondary acetate and regenerated cellulose rayon by means of acetic anhydride in the presence of pyridine are considered. It is shown that the rayons are not degraded when this method of acetylation is employed, and the dependence of solubility on the degree of esterification is briefly discussed. A non-degradative method of hydrolyzing secondary cellulose acetates while in solution, in order to eliminate non-random effects due to a heterogeneous process, or to samples having different molecular orientations, is also given. Author

Cellulose Density

Volume relations in the system cellulose—water. P. H. Hermans, J. J. Hermans, D. Vermaas, and A. Weidinger. (Preliminary communication.) *Rec. Trav. Chim.* **63**, 44–5 (Jan., Feb., 1944) (in English) (through *Bull. Inst. Paper Chem.* **15**, 233, Mar. 1945).

The density of isotropic model fibers of regenerated cellulose of varying water content was determined with an accuracy of 0.001 unit, using the floating method in mixtures of carbon tetrachloride and nitrobenzene. It was found that, with increasing water content, the density first increases, shows a maximum value at about 4% water, and then decreases. These measurements give the external volume—i.e., the swelling with increasing water content—since it could be shown that the water did not penetrate into the interior of the fibers. Up to a water content of 4% in the filaments, the water is bound with a constant apparent density of 1.62. From this point, the apparent density of the water decreases rap-

idly and attains its normal value at a water content of about 22%. An explanation of these observations is derived from the consideration that the dry substance may be regarded as a mixture of empty spaces and cellulose. In this case, the density of the cellulose component is the one measured in water. The latter occupies more and more of the empty spaces until, at a water content of 22%, all spaces are filled and the water is now bound with a "normal" rise in volume. This explanation, which appears to be supported by the results of refractive power determinations, discards the hitherto held concept of an abnormally high density of the bound water and suggests that the density in water, rather than that measured in other media, is the true density of cellulose. This value is higher than that derived from x-ray data for crystalline cellulose. Some properties of and observations made with cellulose are discussed in the light of the author's interpretation.

High-Molecular Wood Cellulose

High-molecular wood celluloses. Nils Gralén and Bengt Rånby. *The Svedberg* (Mem. Vol.), 1944, 274–87 (through *Chem. Abstr.*, 1945, **39**, 1289[6]).

A sulfite pulp prepared with 0.86% CaO and 5.95% SO_2 was sampled from the digester after cooking for 10–16 hours at hour intervals. The lignin content decreased from 16.6 to 2.1% during this time, the pentosans from 4.82 to 3.60%. The solubility increased from 42% to 100% at the end of 14 hours. The viscosity decreased from 7.1 to 6.8 ($\eta sp/c$). Data are given for the sedimentation and diffusion of the nitrates. The molecular weights ($M \times 10^{-3}$) of the nitrate decreased from 2,440 to 590 and the degree of polymerization varied from 9,000 to 2,000; the maximum occurs after 10 hours of pulping. The molecules are of the same order of size as those of the native fiber cellulose. Polydispersity measurements show that the sulfite process possibly has a homogenizing effect on cellulose when most of the lignin has been removed from the wood.

Organic Insulators

Organic insulators in the electrical industry. H. Stäger, W. Bédert and B. Frischmuth. *Schweiz. Arch. angew. Wiss. Tech.* **9**, 261–75, 314–21 (1943); *Chem. Zentr.* 1943, **II**, 2256–7 (through *Chem. Abstr.*, 1945, **39**, 1322[1]).

For a series of synthetic insulators it was shown that there are definite relationships between molecular structure and dielectric properties. The effect of polar groups and the significance of S linkages (vulcanization) with electric moments are discussed. Related to this is the parallelism between dielectric and mechanical properties. In thermosetting polycondensates (phenol-HCHO resins) the freely moving OH groups are primarily responsible for the dielectric losses; this is shown by restricting the mobility of these OH groups by acetylation, methylation, etc. The results of numerous tests are reported. Dielectric properties of mixtures of chlorinated hydrocarbons are represented as a function of their molecular structure. No effect of the molecular structure on the water permeability was found; this permeability depends on intermolecular interstices.

Heat Shrinking of Keratin Fibers

The reactivity and structure of wool keratin. XV. Heat shrinking of keratin fibers. E. Elöd, H. Nowotny, and H. Zahn. *Melliand Textilber.* **25**, 73–7 (1944); cf. *C.A.* **38**, 2825[4], 3137[1]) (through *Chem. Abstr.*, 1945, **39**, 1542[2]).

The preparation of horse hairs for tests, microscopic examination, x-ray diagrams, swelling anisotropy, chemical properties, pancreatin solubility, degradation of horse hairs by water and thermal shrinking of other natural products are discussed. Results: (1) Dry heat causes yellowing and charring of horse hairs. Rapid heating of hair wet only with atmospheric humidity, and heating in water at temperatures above 120° causes shrinking. (2) A decrease in swelling anisotropy was observed. X-ray diagrams show the lines of β-keratin in the microscopically unchanged zones near the part of the fibers which were expanded by the heat reaction. The anisotropy of the lines decreases with increasing heat. The expanded parts of the fibers exhibit an isotropic x-ray diagram. This was called p-keratin and is a degradation product of the β-type. (3) Chemically, singed fibers show a slight cystine damage and solubility of small amounts of proteins and a highly increased enzymic sensitivity. Similar changes occur during heating with water at 130°. Evidently both cases represent a hydrolic degradation which at the higher temperatures and longer exposure periods leads to complete solution of the keratin. (4) Other proteins such as skin keratin and skin collagen show changes of the inner structure of singed preparations, and the phenomena occurring are analogous to those in the case of wool keratin.

Viscosity and Temperature

The amorphous state. XIX. Temperature dependence of the viscosity of liquids. P. P. Kobeko, S. V. Kuvshinskii, and N. I. Shiskin. *J. Tech. Phys.* (U.S.S.R.) **14**, 3–9 (1944) (through *Chem. Abstr.*, 1945, **39**, 1340[2]).

The log of viscosity is plotted as a function of temperature for very different substances: ethers, alcohols, glycerol, organic glasses, B_2O_3, glass, SiO_2, molten salts, molten metals, air. All curves have a similar trend: they are flat for low-melting, steep for high-melting products. In a complete system the viscosity curve of the liquid drops (negative temperature coefficient) to a viscosity of 10^{-1} to 4×10^{-4} poises and, at the critical temperature, reverses to the opposite direction (positive temperature coefficient of viscosity in a gas). It is believed possible to develop a general theory for all liquids.

Weather Resistance of Plastics

Weather resistance of cellulose ester plastic compositions. L. W. A. Meyer and W. M. Gearhart. *Ind. Eng. Chem.* **37**, 232–9 (Mar. 1945).

A number of cellulose acetate butyrate and cellulose acetate plastic compositions were exposed for a period of 2 years to outdoor weathering in Arizona, Florida, and Tennessee. The effect on appearance and physical properties was studied. It was found that degradation is much less pronounced under more temperate climatic conditions. The resistance to weathering can be somewhat improved by the proper choice of plasticizer; it can be materially improved by adding small proportions of an ultraviolet-light inhibitor such as salol. In the case of materials tested, the addition of an inhibitor is effective for both cellulose acetate butyrate and cellulose acetate compositions but is more effective for the former. 10 references.

Authors

BLEACHING: DYEING: FINISHING

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Bleaching Cotton Fabrics

Bleaching cotton fabrics by blowing atmospheric air into a dilute NaOH bath. Justin-Mueller. *Ind. Textile* **60**, 186; *Teintex* **8**, 271–3 (1943); *Chem. Zentr.* **I**, 196 (1944) (through *Chem. Abstr.* **39**, 1764[1], Apr. 20, 1945).

In the process of German Patent 240,037 (*C.A.* **6**, 2177), the cotton is oxidized to oxycellulose and is thereby weakened. $NaHSO_3$ has been used as a preventive of this weakening, but the mode of its action has not been known. J.-M. shows that atmosphere 0 produces an unstable peroxide, probably $Na_4O_2(OH)_2$. The following procedure is recommended: Boil for 8–12 hours with 2°Bé. NaOH and some bisulfite, wash well, acidify, wash and boil in a current of air. Wash again and acidify.

Scouring and Bleaching Rayon

The scouring and bleaching of rayon. Anon. *Silk J. Rayon World* **20**, 40–4 (July, 1944).

As rayons contain fewer natural impurities and generally show higher sensitivity to chemical influences than the parent cellulose, the scouring and bleaching processes utilize similar reagents but for shorter periods of time and at lower concentrations and temperatures. In general, the scouring may be accomplished by use of a 0.3% to 0.5% soap solution to which is added a small amount of Na_2CO_3 or Na_3PO_4. Directions are given for any necessary desizing and for handling of acetate rayon and knitted material. Methods are described for bleaching by the use of a hypochlorite solution which is slightly on the acid side; a very dilute alkaline hypochlorite solution; use of sodium perborate and hydrogen peroxide. Special methods for material containing casein and nylon fibers are also given.

E. G. M.

Pigment Dyes

Printing and dyeing with pigment colors. Winn W. Chase. *Silk J. Ray. World* **21**, 36 (Feb. 1945).

General instructions for printing and dyeing with pigment colors are given. Advantages claimed for these dyes are: their successful use with some of the newer synthetic fibers which have little or no affinity for ordinary dyes; brilliancy of shade; high fastness to light, laundering, and dry-cleaning; greater fidelity of reproduction when used in printing. E. G. M.

Cloth Printing

Patents show possibility of light-printing on cloth. Linton C. Reynolds. *Textile World* **95**, 133, 135 (Apr. 1945).

A discussion of possible future methods of photographic printing of textiles. Three patented methods are described, and procedures and difficulties discussed briefly. The chief objection is cost, but it is thought that with improvements it might be practical in special-purpose fabrics such as bedspreads, slip covers, draperies, etc., which can demand a high price. H. J. B.

Union Dyeing

Union dyeing. Fred Smith. *J. Soc. Dyers and Colourists* **61**, 8–12 (Jan. 1945).

Union fabrics containing various percentages of cotton and wool, such as the woolen type ordinarily made from rags and waste from better cloth, are the most difficult to dye. In order to avoid a cheap appearance in this fabric the cellulose fiber should match the wool exactly or be slightly darker. Sorting the rags into proper classes is important. For dyeing light shades the presence of black or heavily dyed coton-effect threads must be avoided since these cannot be stripped from a woolen piece. Carbonizing can be employed if the reduction in milling properties resulting is acceptable. Dyes suitable for dyeing both wool and cotton in a boiling dye bath and dyes suitable for shading the cotton at a lower temperature are listed. Methods for dyeing navy blues and for "resisting" the wool to the action of the cotton dyes are described. No dyes will dye wool and cotton the same depth of shade equally well under all conditions. It is shown by experiment that with the same wool-dyeing direct dyes a good union dyeing will necessarily be much lighter on a 20–80 wool-cotton mixture than on an 80–20 wool-cotton mixture. It is for this reason that ready-mixed union dyes are not recommended—i.e., they are designed for a definite wool-cotton ratio. Where fast colors on the cotton are desired, sulfur dyes may be used, the dyeing being done in a hydrosulfite and soda ash bath at 110° F. Diazotized and developed dyes are also employed. Dispersed dyes for acetate stain wool heavily and in the case of acetate-wool unions the acetate is dyed first, slowly, the shade on the wool being adjusted later (in a fresh bath if much unexhausted dispersed dye remains). K. S. C.

Wool Dyeing

Wool dyeing: effect of variations in wool. R. H. Kienle, G. L. Royer, and H. R. McCleary. *Am. Dye-*

stuff Reptr. **34**, P42–52 (Jan. 29, 1945).

The factors which cause an increase in the rate of absorption of acid dyes by wool are: natural weathering, light exposure, hydrogen peroxide treatment, sulfoxylate treatment, chemical modification, treatment with cationic active agents, boiling water treatments and treatments with alkaline solutions. The following factors cause a decrease in the rate of absorption of acid dyes by wool: the presence of oils or grease, treatments with hypochlorite, formaldehyde, bichromate, chromic acetate or anionic active agents and resin treatment used for shrinkage control. The pH of the fiber, method of scouring and the fiber size also have an influence on the dyeing rate, while fulling, carbonization and oven drying were found to have little or no effect. Although hydrogen peroxide treatment is listed above as increasing the rate of absorption of acid dyes, such treatment decreases the extent of final exhaustion. Author

Shrink-Resistant Socks

Shrink-resistant treatments for Army woolens. Capt. Harry F. Clapham. *Am. Dyestuff Reptr.* **34**, P68–72 (Feb. 12, 1945).

Although all possible mechanical precautions such as lowering the grade of wool, tightening the stitch and using a proportion of cotton were taken by the Quartermaster Corps to reduce the shrinkage of cushion sole wool socks, shrinkage still caused a large number of failures and unwearable socks. Since actual wear tests showed that certain shrink-resistant processes provided 60% longer wear life, the possible methods of shrink-resistant treatment were intensively investigated. These were: halogenation treatments, the Freney-Lipson process, and enzyme treatments. The halogenation processes are applicable in the available types of hosiery dyeing machines and yield excellent shrinkage control; if this treatment is excessive, however, the wool becomes hard and brittle and its wearing properties are destroyed. (A simple chlorination process consists of adding 4% of 70% calcium hypochlorite to the wet out socks in the dyeing machine, running 20 minutes, antichloring with bisulfite and rinsing.) Resin treatments using the melamine type have shown promise but because of curing complications do not offer any advantages in the treatment of socks. The Freney-Lipson process involves the use of alcohol solution of KOH, CO_2, and alcoholic rinses thus requiring specialized equipment; extremely good results have been obtained by this method however, and it is particularly useful since it may be employed on goods such as finished socks, sweaters and underwear without affecting their color, press or boarding. The enzyme treatment has not as yet shown particularly desirable characteristics especially since the wool fiber seems excessively modified by it. At the present time more than 50% of cushion sole wool socks are being delivered with shrink-resistant treatment. K. S. C.

FIBERS: YARNS: FABRICS: MECHANICAL PROCESSES

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Abrasion Resistance

Abrasion resistance of rayon linings. J. H. Tait. *Can. Text. J.* **62**, 39, 48, 52 (Apr. 6, 1945).

An address in which it is stated that the major factor in deterioration of lining fabrics during normal wear is due to abrasion. Reports are given on the ability of fabrics to resist wear in relation to yarn size, fabric construction, dye method, tensile strengths, and kind of yarn used.

E. G. M.

Automobile Fabrics

Synthetic fabrics for the automotive trade. Morris Saunders. *Can. Text. J.* **62**, 40 (Feb. 9, 1945).

An address outlining the essential requirements of automobile fabrics with special reference to the use of synthetic materials. The widespread use of resin impregnated yarns and fabrics is predicted.

E. G. M.

Tropical Deterioration

Problems in the nature and control of tropical deterioration. H. Weston. *Am. Dyestuff Reptr.* **34**, P91–3 (Feb. 26, 1945).

Large-scale military operations in the tropics have made the problem of deterioration of materials serious and urgent. The climate and the organisms fostered by the climate represent a combination extremely destructive to textiles. It is believed that the deterioration results chiefly from the action of fungi and bacteria; the identity of the most important of the fungi has not yet been definitely established. Some are of the same genera and species notorious for damage to cellulose in this country while others are distinctly different. Although these micro-organisms are best studied singly in pure cultures it must be remembered that under natural conditions they occur in multiple mixtures and that they may quite possibly accomplish in combination what neither component could achieve separately. Though notable advances have been made in the application of chemical mildew-resistant treatments to fabric, samples of tentage recently received from the Pacific theater and badly deteriorated after only three months of use show that there is still much to learn. It is suggested that perhaps the quality of the mildew-proofing might be improved by substituting a two or three bath procedure for the single bath now used for the multiple-purpose type of proofing treatment. There is need for further knowledge of the biochemical activities of fungi in relation to the protective action of mildew-proofing compounds.

K. S. C.

Cotton Ginning

Spinnability of saw-ginned vs. roller-ginned cotton. Simon Williams and Jack Towery. *Cotton* **109**, 110–12 (Apr. 1945).

A report on tests of Stahman Strain 28, Mt. Valley, and Mesa Acala 196 cottons. Saw ginning long staple American Upland cotton yields yarns of equal or better quality.

all factors being considered, than those produced by roller-ginning. Results of the tests are tabulated.
H. J. B.

Recent British Patents

This month's progress in rayon and synthetic fibers. Anon. *Silk and Rayon* **19**, 81, 83, 85–6 (Jan. 1945).

A brief discussion is given of the following subjects: (1) cuprammonium fluidities of cotton and rayon; (2) improving the wet strength of casein fibers (B.P.564,591); (3) extraction of soy bean protein; (4) use of casein fiber in felt-hat manufacture (B.P.564,141); (5) manufacture of shrink-resistant polythene fiber (B.P.564,584); (6) a nylon modified urea resin for coating fabrics (B.P.562,091). E. G. M.

Nylon Tire Cord

Nylon for airplane tires. Anon. *Am. Wool and Cotton Reptr.* **59**, 91, 93 (Apr. 12, 1945).

A report from U. S. Rubber on the use of nylon tire cord. The nylon cord is said to be 225% stronger than cotton and 137% stronger than rayon. Nylon cord tires will take more abuse while a plane is landing than any other tire made. It is expected that 10,000,000 pounds of nylon will be used for tire cord this year. Nylon tires will probably be used for commercial aircraft and heavy trucks after the war. H. J. B.

Developments in Textiles

Developments in textiles in 1944. Milton Harris and Gypsy B. Frankenberg. *Chem. Eng. News* **23**, 147–9 (Jan. 25, 1945) (through *Bull. Inst. Paper Chem.* **15**, 263).

A condensed review of developments in the textile field during 1944 is presented, with reference to waterproofing, fungus-proofing, shrink-resistant treatments, laminated and bonded products, new fibers, and future trends.

Tent-Cloth Treatment

Treating tent cloth with synthetic resins. Anon. *Textile Bulletin* **68**, 24, 26 (Apr. 15, 1945).

A description of the process of coating tent cloths with a compound which seals the relatively open weave of the cloth, rendering it waterproof, and which acts as a binder and carrier for the flame-proofing and fungus-resisting agents. The formula used is described as containing a so-called "Paraplex" resin and an "Amberol" resin. The particular grade of Amerol utilized as a rosin-modified phenolic resin which possesses a high melting point, intrinsic hardness, and the quality, particularly important to tent-cloth manufacture, of being able to release solvent rapidly. Over 12 different ingredients are said to comprise a typical tent-cloth formulation. They are not named. The dry ingredients are mixed in a paddle mixer, liquid components and plasticizer are added, and the mixture is ground in a large roller mill, passed to a series of blend tanks where solvent is added, and finally pumped to coating troughs. The cloth passes through coating tanks and squeeze rolls at from 45 to 60 yards a minute and then through a 60-foot drying tunnel. H. J. B.

Synthetic Fiber Weaving

A general survey of synthetic fiber weaving. Anon. *Silk J. Ray. World* **21**, 26, 28 (Feb. 1945).

A discussion of the principal mechanisms that a loom is composed of. Special emphasis is given to the Crompton and Knowles S type.
E. G. M.

Work Loads

Operative-weight-loads in cotton spinning. J. Buckley. *Text. Mfr.* **71**, 107–8 (Mar. 1945).

Work load of cotton mill help up through the spinning room is discussed. Particular regard is paid to the actual weight of material handled by each operative. It is said that it takes 134 operatives to produce 40,000 lbs. of 36/1 yarn per week of 48 hours on 64,500 mule spindles, whereas a modernized mill with single-process machinery requires 151 operatives to produce 50,000 lbs. of the same yarn per week on 50,000 ring spindles.
H. J. B.

MISCELLANEOUS

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Wood Cellulose

Wood cellulose as a raw material in chemical industry. A. Waller. *The Svedberg* (Mem. Vol.), 1944, 400–12 (through *Chem. Abstr.*, 1945, **39**, 1289[8]).

A general discussion is given of the use of wood pulp for the manufacture of viscose, cellulose nitrate, and cellulose ethers. Tables of analyses are given for cotton linters, viscose pulps from spruce, beech, pine, and *Arundo donax*, and of various European high-alpha pulps.

Color-Blindness

Tests for the detection and analysis of color-blindness: I—The Ishihara test: An evaluation. LeGrand H. Hardy, Gertrude Rand, and M. Catherine Rittler. *J. Opt. Soc. Am.* **35**, 269–75 (1945).

This paper is the first of a series from the Knapp Memorial Laboratories of the Institute of Ophthalmology, New York City, that will evaluate various types of color-blindness tests. The authors conclude that the Ishihara test, taken as a representative type of polychromatic test, fails to give more than a superficial evaluation of an observer's color vision. It can be utilized as a good, rough, screening test for red-green color-blindness but in so doing most of the plates could be discarded. Results depend to a large extent upon the illuminant used. The test gives neither an adequate diagnosis of the type or defect, and may give a wrong diagnosis. D. N.

Cotton Production

Cotton goods peacetime outlook optimistic. Anon. *Am. Wool and Cotton Reptr.* **59**, 7, 9, 145, 151 (Apr. 12, 1945).

Vast market changes are imminent in the respective subdivisions which comprise the cotton goods industry. The tremendous needs of peacetime fabrics indicate that the industry faces an optimistic period after termination of the war. H. J. B.

Cotton Quality in North Carolina

North Carolina cotton and mill requirements. Malcolm E. Campbell. *Am. Wool and Cotton Reptr.* **59**, 29, 31 (Feb. 8, 1945).

A comparison of the wants of North Carolina cotton mills as related to the amount and quality of the raw cotton grown in the State. Staple lengths now produced are those most desired, grade is generally much too low, and character must be improved greatly. H. J. B.

Mill Construction

Planning the construction of your postwar mill. James Osborne. *Textile Age* **9**, 80, 82, 84, 86–90 (Apr. 1945).

The fourth of a series. Fire protection is discussed rather thoroughly, especially the installation of sprinkler systems. H. J. B.

Occupational Illnesses

Occupational illnesses in cotton industries: II—Chronic respiratory probems. Wayne L. Ritter and Morris A. Nussbaum. *J. Ind. Hyg. Toxicol.* **27**, 47–51 (1945); cf. *Miss. Doctor* **22**, 96–9 (Sept. 1944) (through *Chem. Abstr.* **39**, 1993[8], May 10, 1945).

Byssinosis does not exist as a clinical entity among employees exposed to Upland cotton in that industry in Mississippi.

Dan River Research

Dan River reports on research progress. Anon. *Textile World World* **95**, 129, 131 (Apr. 1945).

A description of some results of the research program at Riverside and Dan River Cotton Mills, including seven patented processes and methods developed and now employed by them. H. J. B.

Surface Active Agents

A new approach to the evaluation of wetting, grinding, and dispersing aids. A. E. Bartlett. *Paint Ind. Mag.* **60**, 48, 50–1; *Official Digest Federation Paint & Varnish Production Clubs* No. 243, 76–83 (1945) (through *Chem. Abstr.* **39**, 1770[3], Apr. 20, 1945).

Text of an address. An apparent simplification of the possibilities of surface-active agents is evident if one disregards their effect on dispersion alone and considers their effects on wetting formations, such as faster mixing or getting more pigment in the mix, and their grinding function. If these differences are noted, surface-active agents can be divided into 3 classes—wetting, grinding, and dispersing aids—each of which is capable of quick, accurate laboratory evaluation. Use of this evaluation method prevents missing any important incidental characteristic of the agent.

Textile Education

The undergraduate course in textile chemistry. S. C. Lind. *Am. Dyestuff Reptr.* **34**, P3–6 (Jan. 1, 1945).

The requirements for a sound basic course for the professional training of chemists are discussed. A special five year combination course combining technical and business training is also described. A table is presented showing suggested curricula for a textile chemistry course compared with chemical engineering and chemistry courses. K. S. C.

Higher education and research for textile chemists. H. S. Taylor. *Am. Dyestuff Reptr.* **34**, P7–9 (Jan. 1, 1945).

The research institute of the "convergent" type appears to be the solution of the problem of fundamental research in the highly decentralized textile industry. Educational institutions do not normally provide for both graduate training and opportunity to conduct research in a center where the fundamental science basic to a given industrial field is the major objective of research; the potential value to the textile industry of such an affiliation between an educational institution and a central institute for research in textiles is great. The mechanics of such a liaison to be established between the Textile Research Institute, Inc., and Princeton University is explained. K. S. C.

Tire Cord

Heavier cord speeds tire output. Anon. *Am. Wool and Cotton Reptr.* **59**, 151 (Apr. 12, 1945).

A report from Firestone on the use of heavier rayon cord for military tires. Production is speeded up in the building of the tires because they contain 25% fewer plies. The tires are said to be stronger than the standard rayon cord tires. The cord itself has a tensile strength of 34 pounds as compared with 16½ pounds for the lighter cord. H. J. B.

Water Purification

The use of activated silica in the coagulation of highly colored water. R. E. Noreus. *Paper Trade J.* **120**, 45–7 (Mar. 15, 1945).

When sodium silicate is treated with various chemicals, an activated silica is formed which has been found greatly to improve the coagulation of water. The use of this material in the treatment of highly colored water has resulted in lower settled effluent turbidities, lower filtered water colors, and increased filter runs. Author

Wool Production

Wool goods future indicates heavy demands. Anon. *Am. Wool and Cotton Reptr.* **59**, 125, 127, 129, 131 (Apr. 12, 1945).

Reconversion period is not expected to produce many style changes from pre-war days with plain weaves and pin stripes popular. H. J. B.